ENVIRON
Air Sciences

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Draft Report

AIR QUALITY MODELING ANALYSIS FOR THE SAN JUAN EARLYACTION OZONE COMPACT:
Base Case and Future Case Modeling

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29 January 2004

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1.0 INTRODUCTION

This report describes the results of a photochemical modeling analysis carried out as part of the San Juan Early Action Compact (EAC) Study, described in detail in the modeling protocol by Tesche et al., (2003a). As part of this, a state-of-science air quality modeling system was applied to four ozone episodes during a fifty (50) day long summer ozone period over the Four Corners/San Juan Basin region spanning the 4 June-23 July 2002 timeframe. Within the so-called Summer '02 episode, four (4) embedded high 8-hr ozone episodes occurred in the Four Corners Region. These were:

> Episode 1: (4-8 June 2002);

> Episode 2: (16-19 June 2002);

> Episode 3: (30 June-2 July 2002); and

> Episode 4: (16-18 July 2002).

Nested meteorological and photochemical model simulations were performed by Alpine Geophysics consistent with EPA guidance on the performance testing of models for 8-hr ozone concentrations (EPA, 1999). Technical support for these modeling analyses, particularly with the emissions inventories, was provided by ENVIRON International Corporation.

In this report, we present the results of the operational evaluation of the CAMx photochemical model (ENVIRON, 2003) for the four San Juan ozone episodes. We assess whether the model's performance in simulating three-dimensional fields of ozone and its precursor and product species are adequate for use in estimating attainment of the new 8-hr ozone National Ambient Air Quality Standard (NAAQS) in the Four Corners Region. Based upon successful evaluation of the CAMx modeling system for all four episodes, the model was then used to simulate year 2007 baseline conditions. Simulation of the future year ozone levels in the region allowed estimation of the 8-hr ozone 2007 Design Value (DV) which may be compared directly with the ozone NAAQS. This modeling and analysis faithfully followed the core procedures stipulated in EPA's draft 8-hr modeling guidance (EPA, 1999).

1.1 Background

The EAC Protocol process (Cooke, 2002) requires a state-of-science photochemical grid modeling demonstration to show attainment of the 8-hour ozone standard by December 2007. Any emission controls found through modeling to be necessary for attainment of the NAAQS must be implemented by 2005. Development of a credible photochemical dispersion modeling study, an essential component of the EAC process, was performed by the Alpine/ENVIRON science team under the direction of the NMED Air Quality Bureau staff. Key elements of the EAC:

> Early emission reductions to attain the 8-hour ozone standard;

> Local control of the EAC process, with broad-based public input;

> State support to ensure technical integrity of the early action plan;

> Early action plan incorporated into the SIP;

> Effective date of nonattainment designation and/or designation requirements is deferred (as long as all EAC terms and milestones are met); and

> Safeguards to return to a traditional SIP requirements if EAC terms and/or milestones are not met.

San Juan County qualified for consideration of an EAC because the region currently is in attainment of the 1-hour ozone standard. Since there was a possibility that the regions 8-hr ozone could conceivably approach the 8-hour ozone standard, the NMED elected to opt-in to the EAC in lieu of the possibility of being declared an 8-hour nonattainment area in 2004. There are several significant impacts from being declared an ozone nonattainment area:

> Transportation conformity budgets must be met or highway funds may be cut off;

> Major new or modified construction in the nonattainment area must offset its emissions to build in the area; and

> The area's economic growth is restricted.

To meet the technical milestones required by EPA of EAC Protocol participants, the San Juan 8-hr ozone modeling and analysis work will be completed by 28 February 2004. Completion on this date allows the Early Action Compact to proceed through a public comment period and a New Mexico Environment Department (NMED) hearing. The final Early Action Compact must also go through a legislative process for submittal to the Environmental Protection Agency (Region VI). Consistent with EPA (1999) recommendations, the NMED has established a stakeholder process including the formation of a Technical Peer Review Committee to guide the Alpine/ENVIRON modeling analyses.

1.2 Study Objectives and Methodology

As described in the ozone modeling protocol (Tesche et al., 2003a), the goal of the San Juan EAC 8-hr Ozone Study was to conduct a comprehensive photochemical modeling study for the San Juan Basin/Four Corners Region that could be used as the technical basis for an 8-hr ozone NAAQS modeled attainment demonstration. Guided by the protocol, the modeling analyses were specifically designed to elucidate the main physical and chemical processes and source regions responsible for elevated 8-hr ozone concentrations in the region and to assess whether additional emissions reduction strategies (beyond those already in place due to state and/or federal control programs) are needed in the future. The modeling study objectives and key technical accomplishments are summarized briefly below.

1.2.1 Study Objectives

Major objectives of the San Juan EAC study included:

> Prepare an Ozone Modeling Protocol (Tesche et al., 2003a), consistent with EPA requirements, providing direction to the 8-hr ozone modeling of the San Juan Basin/Four Corners Region. Collaborate with the New Mexico Environment Department (NMED) in

the identification and justification of several 8-hr ozone modeling episodes for the San Juan study;

> Construct dynamically and thermodynamically consistent MM5 meteorological inputs at appropriate grid scales for direct input to the emissions and photochemical models and perform a rigorous model performance evaluation of the meteorological modeling results (Tesche et al., 2003b);

> Produce the model-ready base-year and future-year emissions inventories (Mansell and Dinh, 2003; Mansell, 2004) suitable for input to the CAMx model and perform additional quality assurance (QA) of the emissions data sets developed by the study team and air regulatory agencies;

> Develop photochemical model base case modeling inputs for the selected modeling episode(s) and carry out base case model performance testing, diagnostic analysis, and pertinent sensitivity studies, including a check on mass consistency *(this report);*

> Evaluate the photochemical model's performance for the four base year (2002) ozone episode(s) and compare the results with EPA's performance objectives (EPA, 1999) for 8-hr ozone modeling *(this report);*

> Estimate future-year (2007) baseline 8-hr ozone levels in the San Juan County region and perform a modeled ozone attainment demonstration consistent with EPA guidance (EPA, 1999) to assess whether additional control measures (beyond those already in place) are needed for a modeled demonstration of attainment with the 8-hr NAAQS *(this report);*

> Perform a variety of future-year (2007) emissions change and source apportionment simulations to examine the sensitivity and uncertainty of the future ozone conditions (and hence the robustness of the modeled attainment demonstrations) given the various uncertainties in modeling future years (e.g., county growth rates, implementation and effectiveness of local and distant upwind control measures);

> Develop supplementary "weight of evidence" analyses supporting the ozone attainment demonstration modeling aimed at assisting the NMED in developing the technical information required for the San Juan County 8-hr ozone Early Action Compact documentation;

> Provide for a thorough and efficient transfer of modeling codes, data sets, and related information (e.g., public information presentations) to stakeholders during the process.

Each of these objectives was met following the technical approach set forth in the San Juan EAC protocol. In this report, we discuss the results of the base year model performance testing and the year 2007 ozone attainment demonstration modeling. In a companion report, we present the results of the future-year (2007) emissions change and source apportionment simulations.

1.2.2 Ozone Modeling Protocol

The San Juan 8-hr ozone modeling protocol (Tesche et al., 2003a) was developed at the beginning of the study and submitted for external peer review by the U.S. EPA, stakeholders, and the public. The protocol documented the modeling assumptions and activities associated with the San Juan EAC 8-hr ozone study. Specific activities and technical approaches prescribed in the protocol included: (a) selection of appropriate models, data bases, and episodes, (b) evaluating the performance of the full modeling system, and (c) use of the models and input data bases to estimate the levels of VOC and/or NOx emissions controls potentially needed to maintain and/or attain the 8-hr ozone standard in the San Juan Basin region. The modeling approach identified in the protocol was review by the NMED, pertinent EPA regional offices, a Technical Peer Review Committee, and other stakeholders. Based on comments received, the protocol was refined and served as the framework for carrying out all subsequent modeling and technical analyses.

1.2.3 Episode Selection Report

Identification, selection, and characterization of suitable episodes for 8-hr ozone modeling was a key component of the San Juan Early Action Compact study. As described in the Episode Selection Report (Tesche et al., 2003c), this activity was carried out consistent with EPA guidance on 8-hr ozone modeling and with established practice in regulatory photochemical modeling. The report discussed the episode selection process employed for the San Juan EAC study and also presented a brief conceptual model of the aerometric conditions associated with high 8-hr ozone episodes in the San Juan Basin. These analyses built upon existing air quality and meteorological study results and findings assembled by the Air Quality Bureau of the NMED.

The main components of the San Juan episode selection process included:

> Identification of the policy and technical issues influencing episode selection for regulatory 8-hr ozone attainment modeling;

> An objective episode selection process based on: (a) analysis of historical air quality and meteorology in the region, (b) synthesis of past studies, and (c) the consideration of the conceptual nature of the types, character, and frequency of occurrence of 8-hr ozone episodes in the San Juan Basin/Four Corners region;

> Development of a prioritized list of recommended episodes complete with supporting air quality and meteorological analyses of the preferred period(s); and

> Construction of an initial conceptual model of each recommended modeling period.

The episode selection report summarizing the key policy and technical issues associated with 8-hr ozone episode selection, consistent with EPA's episode selection recommendations. We summarized the specific technical steps in identifying and evaluating candidate 8-hr ozone episodes for the study area. These analyses were supplemented with trajectory analyses aimed at identifying the general weather types and transport patterns associated with candidate episodes. We developed a brief conceptual characterization (i.e., conceptual model) of the conditions that lead to elevated 8-hr ozone concentrations in the San Juan region and then presented our recommendations for the four episodes to be modeled. The connection between the four San Juan modeling episodes chosen and the modeling periods that used in the parallel Denver-Northern Front Range EAC study were identified as well.

1.2.4 Meteorological Modeling Report

Meteorological inputs required by the CAMx photochemical and the EPS2x emissions models include hourly estimates of surface pressure and clouds; the three-dimensional distribution of winds, temperatures, and mixing ratio; and other physical parameters or diagnosed quantities such as turbulent mixing rates (i.e., eddy diffusivities) and planetary boundary layer heights. The MM5 performance evaluation (Tesche et al., 2003b) carried out early in this study centered on comparisons between surface and aloft meteorological measurements routinely collected over the Four Corners Region using the air quality model-ready meteorological fields derived from the MM5 model outputs. The principal aim of the evaluation was to assess whether the simulated fields from the meteorological modeling systems may be relied upon to provide wind, temperature, mixing, moisture, and radiation inputs to the CAMx model for typical high 8-hr ozone periods in the San Juan/Four Corners Region. As described in Tesche et al., (2003b) we assessed the MM5 model's performance using a combination of statistical measures and benchmarks, graphical tools, and more qualitative 'weight of evidence' considerations for one primary purpose: to judge the adequacy of the meteorological results as input to regulatory 8-hr ozone modeling for the San Juan EAC. This was accomplished, in part, by comparing the MM5's performance in simulating the four ozone episodes with results from 57 regulatory model evaluations in U.S. using the MM5 (or similar models) in direct support of 1-hr or 8-hr ozone NAAQS decision-making.

Since there are no currently accepted performance criteria for prognostic meteorological models used in ozone SIP decision-making, we utilized recently proposed *ad hoc* benchmarks and evaluation results from 57 recent regulatory ozone modeling studies to assess the current MM5 modeling results developed for the Summer '02 episode at 36/12 km scale and Episodes 1 through 4 at 4 km scale. The MM5 application to the Summer '02 episode and the four 8-hr modeling episodes exceeded many but not all of the *ad hoc* statistical benchmarks. In other instances, the model's performance for temperature and/or wind composite statistical measures fell somewhat outside of the typical performance levels achieved in other regulatory studies. Through subsequent diagnostic analyses, we attributed these performance issues to: (a) the technical challenges of modeling mesoscale ozone episodes over the Intermountain West, (b) the extreme topography, (c) the occurrence of one of the driest periods on record and the concomitant widespread atypical soil moisture levels, (d) limited observations, and (e) the effect of drought conditions on modeled surface temperature predictions.

Although certain of the MM5 statistical measures such as temperature bias and error, wind speed RMSE error, wind direction error fall somewhat outside the *average* performance levels achieved in other regulatory evaluations, the current San Juan MM5 results—in aggregate--were still *well within the envelop of prognostic model performance* that has been judged acceptable for 1-hr and 8-hr regulatory ozone modeling studies elsewhere in the U. S. Based on supplemental 'weight of evidence' information (see for example, Tesche et al., Chapter 13) we concluded that the MM5 meteorological fields were quite adequate for use as input to the regional emissions and photochemical models for the four San Juan 8-hr EAC ozone episodes.

1.2.5 Base Year Emissions Inventory Report

Mansell and Dinh (2003) describe the emissions modeling and analysis performed by ENVIRON in support of the CAMx photochemical modeling for the San Juan County EAC. Their report on the base year emissions inventory development focused on a 36/12/4 km nested-grid modeling domain that includes Mexico in the south to Wyoming in the north and California in the west to western Missouri to the east. Base year emissions development was are similar to and coordinated with the parallel 8-hour ozone EAC modeling for the Denver, Colorado area for the Denver Regional Air Quality Council (DRAQC) and the Colorado Department of Public Health and Environment (CDPHE) (see, Tesche et al., 2003d).

For the 4 June to 23 July 2002 modeling period, emission inventories were processed using version 2x of the Emissions Processing System (EPS2x) for area, off-road, on-road mobile and point sources (ENVIRON, 2001). The purpose of the emissions processing was to format the emission inventory for CAMx photochemical modeling. Data sources and processing steps required to develop the emission inventory are documented in the following sections. In the San Juan Emissions Modeling Report, Mansell and Dinh (2003a) discuss each of the emission processing steps required to develop the model-ready emission inventory for the four 002 base case ozone episodes. The report identified the various data sources and processing steps needed in the development of day-specific inventories for each modeling day during 2002. In addition, summary tables and figures were presented that summarized the modeling inventory by major emission source category: area, on-road mobile, off-road mobile, stationary point sources, oil and gas development sources and biogenics.

1.2.6 Future Year Emissions Inventory Report

Mansell (2004) describes the development of the year 2007 emissions inventories used in the future year photochemical modeling for the San Juan EAC. This report builds on the base year emissions inventory report summarized above and similar to and coordinated with the parallel 8-hour ozone Denver EAC modeling. Based on local, state, and national estimates of population and industrial growth and the effects of emissions control currently ‘on the books’, a set of CAMx-ready modeling inventories were prepared for each modeling day during the 4 June to 23 July 2002 period. Projected emission inventories were developed using EPS2x for area, off-road, on-road mobile, point sources, and biogenic sources. The future year emissions report identified the data sources available for quantifying future growth and control assumptions. In most cases, San Juan county specific data were not available from local sources so state and federal growth and control estimates had to be used. (The impact of the most important of these growth and control assumptions were later tested via CAMx sensitivity and uncertainty testing in the companion control study report by Tesche et al., 2004d.) The future year emissions inventory report presented summary tables and figures for each major emission source category including area, on-road mobile, off-road mobile, stationary point sources, oil and gas development sources, and biogenics.

1.3 Report Structure

In Chapter 2, we present a brief overview of the four San Juan EAC modeling episodes. The CAMx base case model performance evaluation exercise is discussed in Chapter 3 where we present the key results and findings consistent with EPA guidance on model testing. Chapter 4 addresses the year 2007 future baseline ozone modeling and presents the main findings. Then, in Chapter 5 we present the methodology and results of the formal 8-hr ozone attainment demonstration. Our summary and conclusions are offered in Chapter 6.

2.0 THE MODELING EPISODES

The study team collaborated with Air Quality Bureau staff in the identification and justification of four 8-hr ozone modeling episodes for the San Juan County study. Because EPA 8-hr modeling guidance and the Early Action Compact Protocol (Cooke, 2002) suggest multiple 8-hr modeling episodes, we worked with the Bureau staff and stakeholders to identify high-priority 8-hr ozone episodes within the 1999-2002 time frame. NMED staff had already analyzed the meteorological and air quality data in the region and we adopted and extended these statistical summaries to identify specific modeling periods consistent with EPA guidance. The San Juan Ozone Modeling Protocol (Tesche et al., 2003a) discusses the details of the episode selection process for the San Juan EAC study. Here we summarize the main characteristics of the four modeling episodes before presenting the results of the base case and future year ozone modeling in subsequent chapters.

2.1 Modeling Episodes

Figures 2-1 and 2-2 present the 8-hr ozone daily maxima for fifty (50) day long Summer '02 episode and the four embedded modeling episodes in the San Juan Basin/Four Corners Region. In view of EPA's emergent recommendations on 8-hr ozone episode selection and based on our review of the hourly ozone measurements at the various ozone monitors in the intermountain west, particularly at the Bloomfield, Substation, Bondad, Ignacio, and Mesa Verde monitors, four (4) discrete ozone episodes shown in Figure 2-2 were selected for modeling included:

> Episode 1: 4-8 June 2002;
> Episode 2: 16-19 June 2002;
> Episode 3: 30 June-2 July 2002; and
> Episode 4: 16-18 July 2002.

The modeling strategy was to simulate each episode at three scales: 36/12/34 km. This allowed for direct inclusion of the potential impact from emissions from far upwind source areas such as southern California, Mexico, Texas, Utah, and Denver-Colorado Springs on air quality levels in the Four Corners Region. The 4 km grid was inserted within the parent 36/12 km regional grids to simulate with higher precision the local emissions, transport, transformation and removal processes within the study area.

Modeling these four 8-hr ozone modeling episodes has the following specific advantages relative to other elevated 8-hr ozone periods in 1999-2002:

> The daily maximum ozone concentrations during these four episodes are very close to the current (2001-2003) 8-hr Design Value (DV) in the region (74.7 ppb), consistent with EPA recommendations. Other potential modeling periods with peak 8-hr concentrations significantly higher than the current DV (e.g., 2-4 Aug '00), are more severe than required by EPA guidance and these could conceivably generate unnecessarily greater emissions control requirements for attainment and maintenance of the NAAQS;

> All four episodes fall within the most recent[1] year (2002); accordingly, the emissions estimates developed for these episodes was based on the most recent, representative emissions conditions in the region;

[1] When this study began, 2002 was the most recent year for which full ozone data were available.

> All of the episodes are multiple-day in nature;

> A variety of meteorological conditions and potential source-receptor conditions were available for examination; and

> A sufficient number of days would be modeled such that EPA's 8-hr Attainment Test can be applied at all five monitoring stations in the Four Corners region.

Finally, use of the Summer '02 ozone episode allowed the San Juan County modeling study to take maximum advantage of the parallel 8-hr EAC modeling being performed by the study (Tesche et al., 2003d) in the Denver region through the Denver Regional Air Quality Council (RAQC). The first San Juan episode coincides with Episode 3 (5–10 June '02) in the Denver study while the fourth San Juan episode coincides with Episode 1 (16–22 July '02) for Denver. The second episode being modeled in the Denver study overlaps with the San Juan Episode 3 (30 June – 3 July '02).

2.2 Characteristics of the Modeling Episodes

Some of the more salient conceptual characteristics of each modeling period based on information readily at hand is given below, beginning with a summary of the climatology and air quality conditions of the region.

2.2.1 Climate, Meteorology, and Air Quality of the San Juan Basin

The San Juan Basin experiences cool, dry winters and warm, dry summers, consistent with its location in the arid continental Great Basin. Abundant sunshine and large diurnal temperature ranges occur in the region, largely as the result of the significant distance from major oceans. Maximum precipitation occurs in the region in late summer and early fall as the result of moisture transport from the Gulf of Mexico under the western extension of the Bermuda High. Much of this precipitation derives from afternoon convective thunderstorms that occur during the late summer 'monsoon' season. In the more mountainous terrain to the north (i.e., the San Juan and La Sal Mountains) wetter and cooler conditions prevail compared to those in the Aztec-Farmington-Bloomfield area.

Annual precipitation at Farmington is 8.8 inches. Early summers are dry while later in the summer, as noted above, precipitation in the Farmington area is at it greatest. During the 1978-2000 period of record, the driest and wettest months in Farmington were June and August, when 0.3 and 1.2 inches of rain occurred (BLM, 2003). Late summer (August) average high and low temperatures at the Farmington airport were 90 F^0 and 59 F^0.

Synoptic winds over the San Juan Basin are westerly to southwesterly throughout much of the year. At night, local drainage flows can override the synoptic winds, producing locally channeled flows aligned along the San Juan River drainage and other terrain features. Indeed, the east-west orientation of the San Juan River as it leaves Navajo Reservoir induces a high frequency of west and east winds when measured at the Bloomfield monitor. There is also evidence at the Bloomfield monitor of nocturnal drainage flows off the elevated terrain to the north.

Ozone air quality in the San Juan Basin is generally good although this assessment derives from fairly limited monitoring information from the two existing regulatory monitors (Substation and

Bloomfield) in northwest New Mexico and from historical surface and aircraft ozone monitoring and modeling studies in the region (see, for example, Tesche and Ogren, 1976; Tesche et al., 1976). Routine ozone monitoring began at the Substation monitor in 1997 and routine 8-hr ozone monitoring at the Substation and Bloomfield monitors covers the period 1999-2003. (Actually, the Bloomfield monitor became fully operational in 2000). From this brief record, no 1-hr violations of the National Ambient Air Quality Standard (NAAQS) have been recorded in the San Juan Basin. In addition, no exceedances of the 8-hr ozone NAAQS have been reported at the two regulatory monitors. Note however, that in 2000, maximum 8-hr ozone concentrations at Bloomfield reached 85 ppb. A peak of 84 ppb was monitored at Substation. While the maximum ozone value at Bloomfield exceeds the concentration level of the 8-hr standard, it does not constitute an exceedance of the ozone standard. Violations of the 8-hr ozone standard occur at a monitor when the three-year running average of the annual fourth highest daily maximum 8-hour ozone concentrations exceeds 84.5 ppb. For both Bloomfield and Substation monitors over the most recent three-year period (2001-2003), the three-year running average is 74.3 and 74.7 ppb, respectively. The 8-hr design values at the Mesa Verde, Bondad, and Ignacio monitors in southwestern Colorado are all less than these. Thus, 74.7 ppb is the current 8-hr ozone Design Value (DV) for the San Juan region.

2.2.2 Episode 1: 4-8 June 2002

The 4-8 June 2002 episode occurred on Tuesday through Saturday. The highest 8-hr ozone levels recorded at Substation and Bloomfield during the 5-8 June period were 76 and 80 ppb respectively. During this period, the Substation monitor recorded three days wherein the peak 8-hr ozone values were close to the current 2001-2003 Design Value of (74.7 ppb). These were 75 ppb, 77 ppb, and 76 ppb on 5, 7, and 8 June respectively. A peak 8-hour ozone concentration of 80 ppb was measured at Bloomfield on 5 June ozone levels at this site dropped considerably for the rest of the period.

Back trajectories calculated using the NOAA HYSPLIT model for each day of the 4-8 June ’02 period indicate that the episode includes three distinct synoptic scale transport patterns (i.e., three different meteorological regimes) all occurring within a single multiple-day episode. On the 5th, wind transport at the ground and aloft is from the north, veering to the northeast as the air parcels enter the Farmington region. Winds at the surface and at 100m appear to come down the Animas river drainage from the Durango area while the aloft winds on the 5th have more northerly path. On the following day, a transition in synoptic transport conditions is evident. Surface and low level (i.e., 100m) flows come from the southeast whereas aloft, the wind are northerly and northwesterly. The synoptic transition is stabilized on the 7th and 8th of June where the winds at the ground and aloft come from the southwest—the predominant synoptic flow direction for historically high 8-hr ozone concentrations in San Juan County.

2.2.3 Episode 2: 16-19 June 2002

The 16-19 June 2002 episode occurred on Sunday through Wednesday. The highest 8-hr ozone levels recorded at Substation and Bloomfield during the episode were 80 and 76 ppb respectively. The peak value at the Substation monitor was 80 ppb on Monday 17 June, while the maximum at Bloomfield occurred on the 19th with a reading of 76 ppb, slightly higher than this station’s current Design Value of 74.3 ppb. The 8-hr ozone peak at Substation (80 ppb) is slightly higher than that stations current 8-hr DV (74.7 ppb). As shown in Figure 3-2, the winds during Episode 2 were the lightest of any of the four episodes to be modeled, enhancing the likelihood that local stagnation conditions will be captured at times during this episode.

Backward HYSPLIT trajectories for 16-19 June '02 indicate that the entire episode fell under a common southwest synoptic flow regime. To be sure, there is day-to-day variability in the surface and aloft trajectory paths leading to the Farmington area on all three days but the general synoptic pattern is remarkably consistent across the 72-hour period.

2.2.4 Episode 3: 30 June-2 July 2002

The 30 June-3 July 2002 episode occurred on Sunday-Wednesday. The highest 8-hr ozone level recorded was 76 ppb at the Bloomfield monitor. Backward trajectories on 2 July '02 indicate source regions in southeastern Utah and a generally northerly flow into the Farmington area at the ground and aloft. From Figure 3-2, the winds during Episode 3 were also fairly light, compared with the other episodes, enhancing the likelihood that local stagnation conditions may be captured at times during this episode as with Episode 2.

2.2.5 Episode 4: 16-18 July 2002

The 16-19 July 2002 episode occurred on Tuesday-Friday. The highest 8-hr ozone level recorded was 79 ppb at the Bloomfield monitor. This peak is slightly higher than the station's current Design Value (74.3 ppb). Backward trajectories on 18 July '02 indicate source regions in southeastern Utah and northeastern Arizona and a generally a westerly flow up the San Juan River drainage into the Farmington area at the ground and aloft.

2.3 Role of Wildfires During 2002

Concerns were raised regarding the extent to which VOC and NOx emissions from wildfires burning in the western states during the Summer '02 period (4 June-19 July 2002) may have contributed to the ozone levels recorded in San Juan County during the four intensive 8-hr modeling episodes. A key question was whether wildfire emissions influenced peak ozone readings in the San Juan Basin to any significant degree, and if so how should this be addressed in the modeling? We examined the 8-hr ozone data at the Substation and Bloomfield monitors for the all modeling days during the four 8-hr ozone episodes. Particular emphasis was placed on the potential impact of fires on these episodes. The major fires potentially affecting the Four Corners region included:

- The Missionary Ridge Fire (Durango): began 9 June and ran through 19 July;
- The Rodeo Fire (central Arizona): began 18 June and ran through 7 July;
- The Chedeski Fire (central Arizona): began 20 June and ran through 7 July;

Our analysis of each episode entailed examination of available satellite imagery and regional wind trajectory modeling analyses which: (a) revealed the local and regional extent of visible smoke plumes from various fires burning in the southwest during the Summer '02 period, and (b) the likely trajectory paths followed by the wildfire emissions plumes. Our findings were as follows.

Episode 1: (4-8 June): None of these fires impacted the 4-8 June episode (they hadn't started).

Episode 2: (16-19 June): The Missionary Ridge Fire likely didn't impact this episode. Figures 3-4e-g in the San Juan Ozone Modeling Protocol show the surface and aloft regional winds out of the southwest.

The Missionary plume would have been carried northeastward toward Lake and Gunnison counties in Colorado. This is corroborated by MODIS satellite visible plume imagery from the Colorado fires (Missionary Ridge Fire, Hayman) burning on 19 June (Day 170). The synoptic weather on the 19th, confirming the HYSPLIT results on Figures 3-4e-g, show the plumes from the various fires moving toward the northeast. The MODIS satellite data shows the visible Rodeo plume at 1825 CST on 19 June (Day 170). The plume was still in it's infancy (just started the day before) and while it was moving toward the northeast (Gallup, NM) it was still a long way from Farmington and the Four Corners area. Thus, it appears to be very unlikely that the first two episodes were impacted at all by the Missionary, Rodeo, or Chedeski fire complexes.

Episode 3: (30 Jun-2 July). No satellite data were available on these dates. Figure 3-4h in the protocol shows the potential for transport from the north on 2 July. However, the HYSPLIT surface and aloft winds (an interpolation of measured winds across the western states NWS monitoring sites) were at odds with the local surface weather observations at the Bloomfield and Substation ozone monitors on the 1st and 2nd.

At Bloomfield, from midnight to 4 am, the surface winds were out of the north at about 1.4 m/s. But beginning at 5am through 2000 hours, the winds were not coming from the north, but rather had shifted to the south to southwest. Light northerly winds at Bloomfield returned at 2100 hours and continued through 0500 on 2 July, when the winds again shifted, coming from the southwest through the southeast for the remainder of 2 July. North winds did not result at Bloomfield until the early morning hours on the 3rd. Thus, these northerly flows on 1-3 July appear to be limited to nighttime hours, are the result of nocturnal drainage of the sloping terrain immediately north of Bloomfield, and do not appear to be larger synoptic scale transport from the San Juan Mountains/Durango area where the Missionary Ridge fire was burning.

At the Substation monitor, the surface winds were consistently out of the west for most of the 30 June-2 July period. Thus, examination of the local flow fields in the Farmington area showed no plausible linkage between the Missionary Ridge fire (> 100 miles north) and local wind patterns near the two San Juan County ozone monitors.

Episode 4: (16-18 July). The Rodeo/Chedeski Fires were out by the time this episode occurred. Missionary Ridge was contained by 19 July. The synoptic wind trajectories on 18 July (Figure 3-4i in the protocol) show persistent westerly winds at the ground and aloft on this day. Examination of the surface wind records at Bloomfield and Substation on 18 July show that the local winds were persistently upriver (i.e., out of the west to northwest) for most of the day. Thus, as with the 1-2 July episode, preliminary examination of the local flow fields shows no plausible linkage between the Missionary Ridge fire and local impacts at the two San Juan County ozone monitors.

Based on our analyses, we saw no direct evidence of wildfire impacts in the Farmington region from the Rodeo, Chedeski, Missionary Ridge or Hayman fires during any of the days used in the San Juan EAC modeling. The only possible indication of an impact is the HYSPLIT trajectory results on 2 July (Figure 3-4h of the protocol). But even in this plot, the primary transport path is westerly. Even if there was aloft transport on this day from the Missionary Ridge fire (overriding the southerly flows at the ground level monitors), the fire plume would still need to mix to ground in appreciable quantities to affect ozone. Furthermore, sufficient NO or NO_2 would need to be retained in the fire plume to have an influence on ozone photochemistry. Given the fairly short lifetime of NO/NO_2 before it is removed chemically or physically, and the longer physical transport time from the Durango/Missionary ridge fire to Farmington, it is doubtful that photochemically active NOx would remain in appreciable amounts to impact ozone concentrations in the Four Corners region.

2.4 Concluding Remarks

A general conceptualization 8-hour ozone formation in the San Juan Basin/Four Corners Region is as follows. High ozone concentrations generally occur in the Farmington area on days that are hot, cloud-free, and with light wind speeds at both at the surface and aloft. Most 8-hr ozone events occur on days when high temperatures are above 90 degrees F and when winds are out of the southwest to northwest quadrants. Occasional episodes occur under northerly synoptic flow conditions. Episodic ozone events of two or more days are not uncommon in the San Juan Basin where temperatures above 90 degrees F persist for several days in a row.

Though not necessarily correlated with the occurrence of regional wild fires, ozone episode periods occasionally overlap with periods of wildfire in the western U.S. (see Figures 3-3 through 3-5). The highest 8-hr ozone levels usually occur from early June to late July and sometimes-early August. Based on the analyses summarized in the protocol and episode selection reports (Tesche et al., 2003a,c), the meteorological inputs from the MM5 model were produced on the 36/12 km regional grid for the period beginning 1200 UTC (0500 MST) on 3 June 2002 extending through 1200 UTC (0500 MST) on 23 July 2002. The higher resolution (i.e., 4 km) MM5 simulations were implemented during the following periods:

- 1200 UTC (0500 MST) on 4 June through 1200 UTC (0500 MST) on 9 June;
- 1200 UTC (0500 MST) on 16 June through 1200 UTC (0500 MST) on 20 June;
- 1200 UTC (0500 MST) on 30 June through 1200 UTC (0500 MST) on 3 July; and
- 1200 UTC (0500 MST) on 16 July through 1200 UTC (0500 MST) on 19 July.

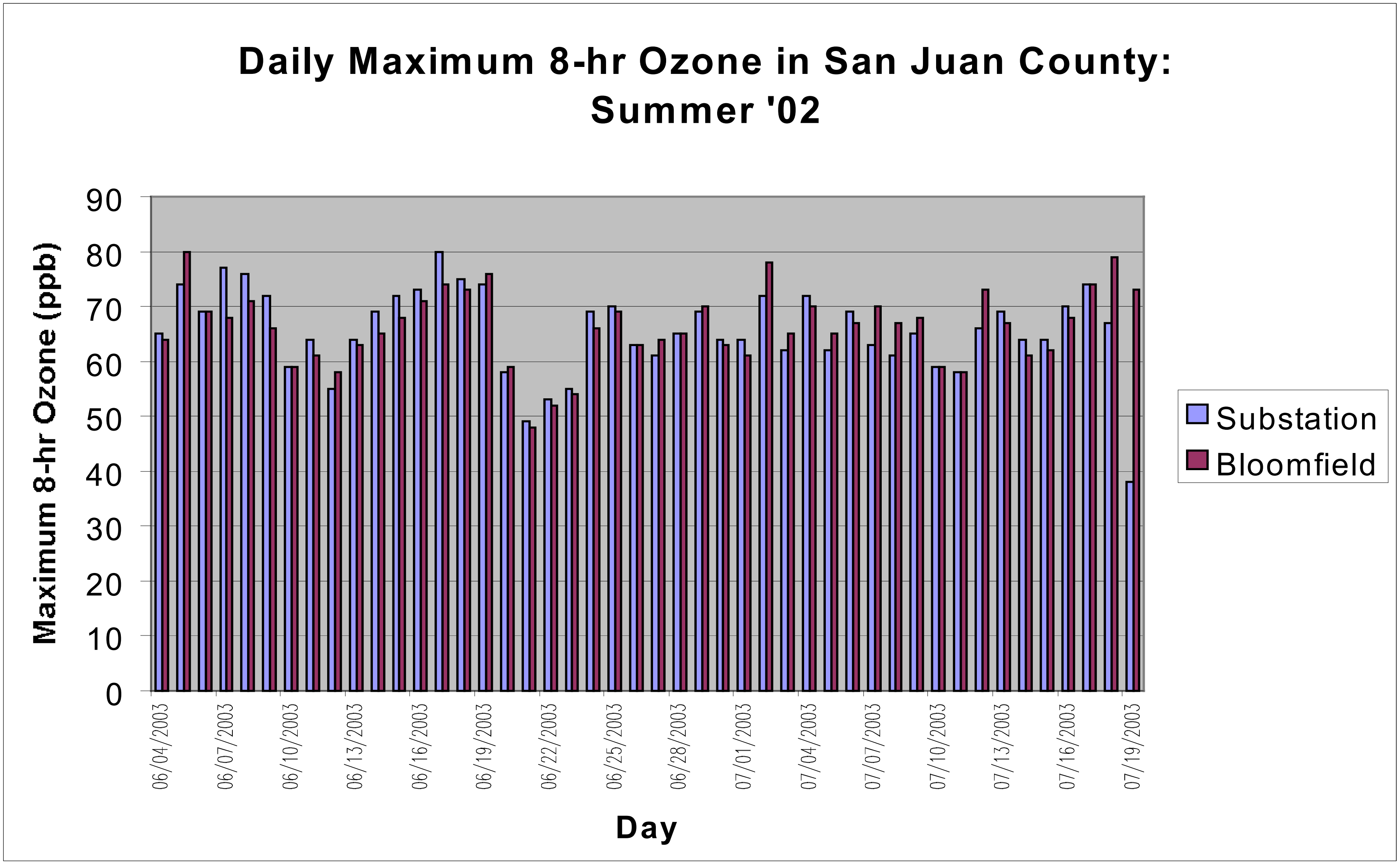

Figure 2-1. **Daily Maximum 8-hr Ozone Concentrations at Substation and Bloomfield During the Summer ’02 Episode in the Four Corners Region.**

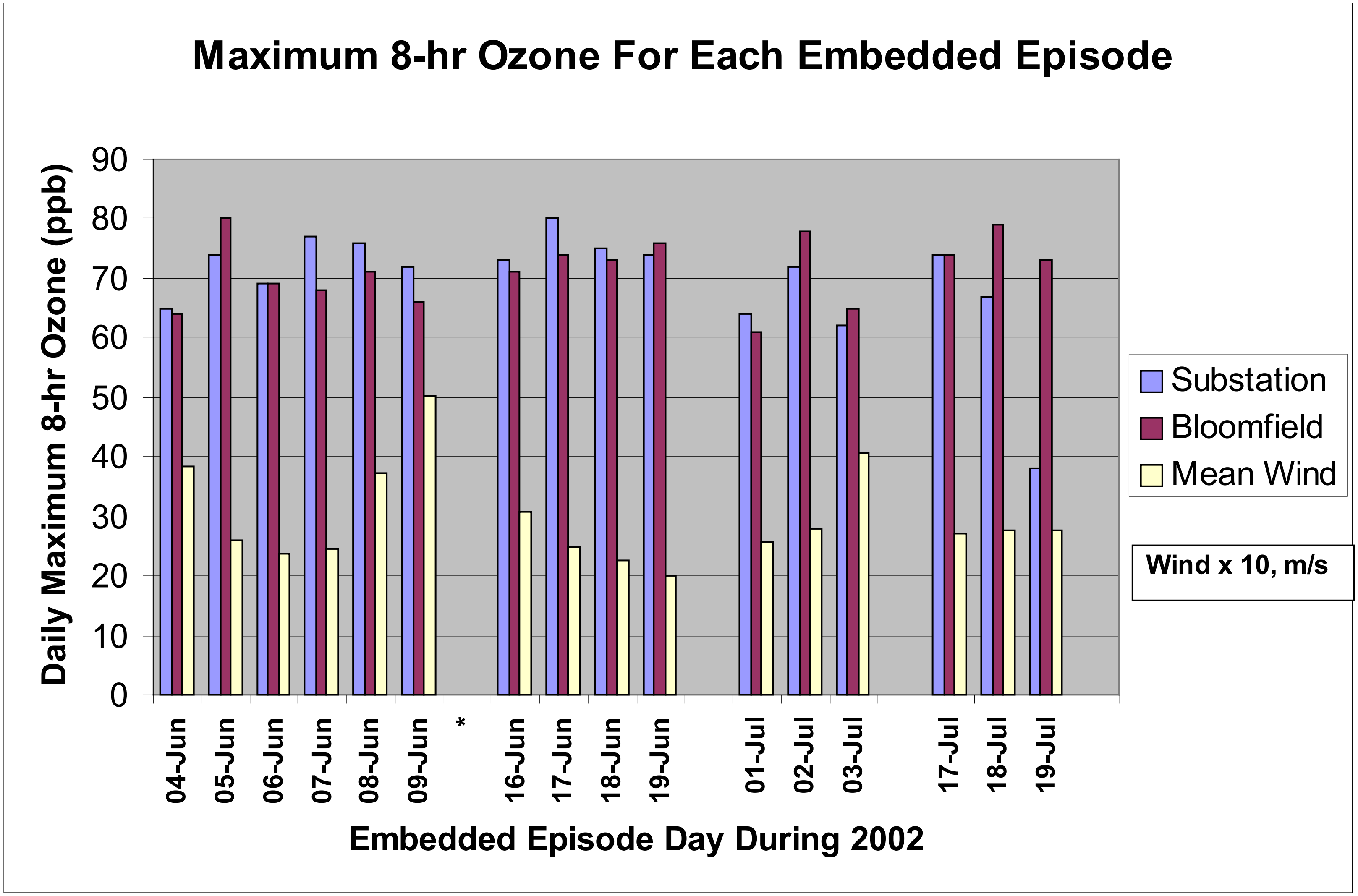

Figure 2-2. Daily Maximum 8-hr Ozone Concentrations at Substation and Bloomfield During the Four Embedded Episodes in the Four Corners Region. (Also shown is the mean wind speed at the Bloomfield Monitor during each day.)

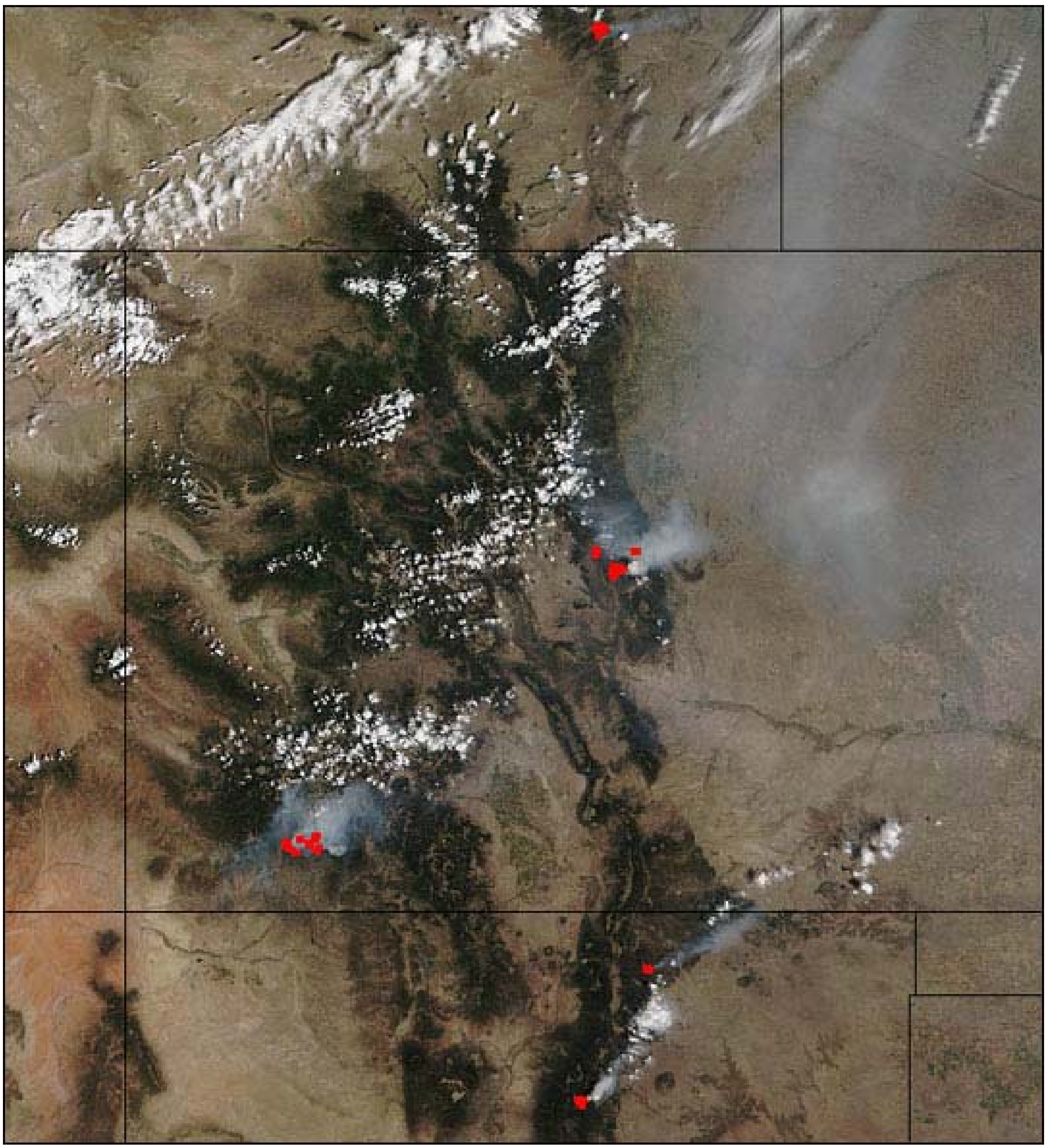

Figure 2-3. Satellite Imagery of Fires in Colorado and New Mexico on Day 170 (19 June 2002).

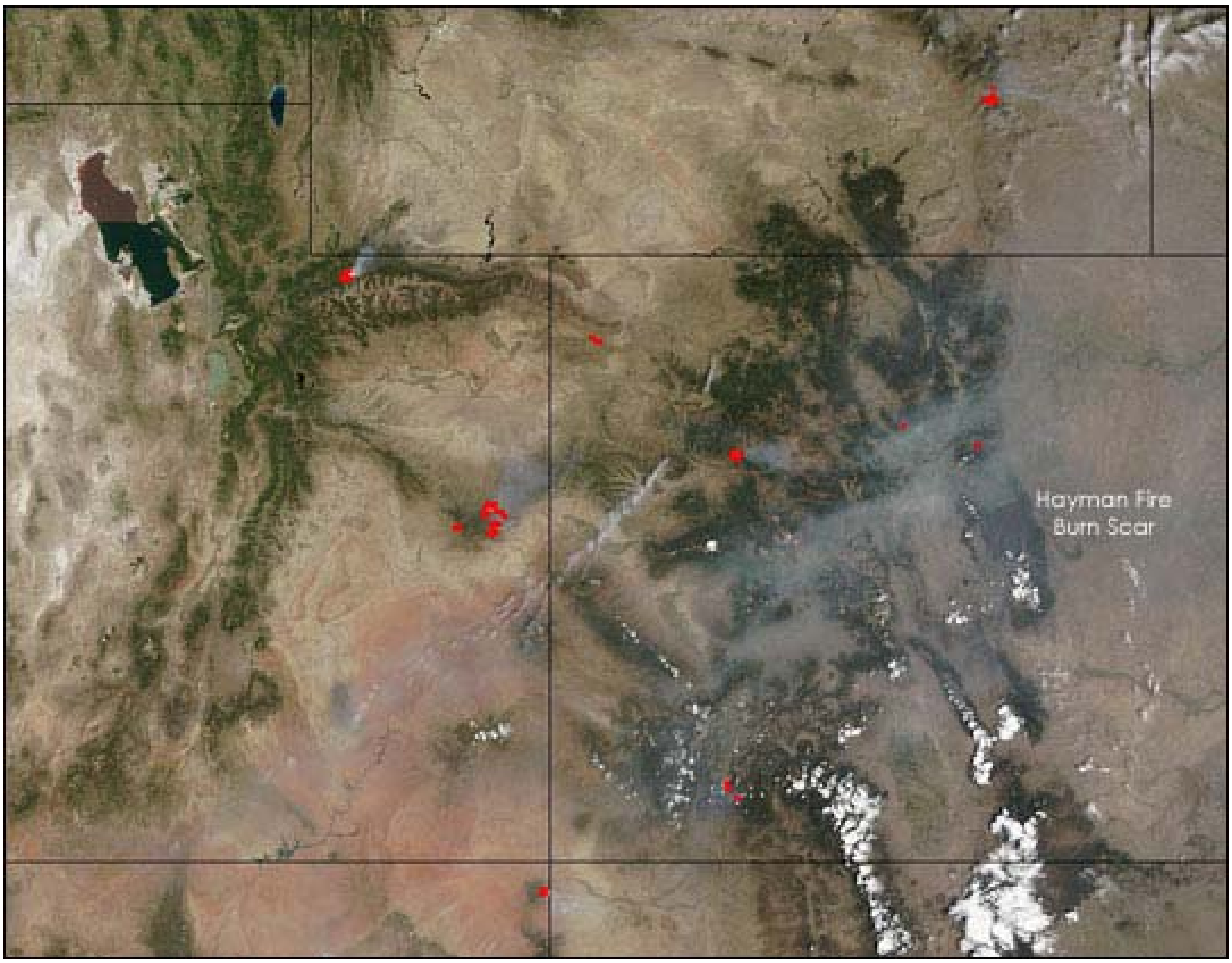

Figure 2-4. Satellite Imagery of Fires in Colorado and New Mexico on Day 181 (30 June 2002).

3.0 BASE CASE MODEL PERFORMANCE EVALUATION

Model performance evaluation (MPE) is the process of testing a model's ability to estimate accurately observed atmospheric properties over a range of synoptic and geophysical conditions. From a scientific perspective, the process, when conducted thoughtfully and thoroughly, focuses and directs the continuing cycle of model development, data collection, model testing, diagnostic analysis, refinement, and re-testing. From a regulatory perspective and the one adopted here, the process leads to a judgment as to whether the modeling system exhibits sufficient accuracy and prediction skill in replicating past events that it may be used with confidence in assessing the effects of future emissions growth and controls in a region. In this chapter we present the evaluation of the CAMx photochemical model for the four San Juan base case ozone episodes. We begin by summarizing the philosophy and objectives that governed the evaluation and then identify the specific evaluation methods employed to judge the suitability of the CAMx models for an 8-hr ozone EAC regulatory application, using common statistical measures and graphical procedures to elucidate model performance. This evaluation plan conforms to the procedures recommended by the EPA (1991, 1999) for 1-hr and 8-hr ozone attainment demonstration modeling.

3.1 Overview

3.1.1 Evaluation Principles

Our evaluation of the MM5/CAMx modeling system (i.e., the emissions, meteorological and dispersion models and their supporting data sets) was guided by the principals:

> **The Model Should be Viewed as a System.** When we refer to evaluating a "model", we mean this in the broad sense. This includes not only the CAMx photochemical model, but its various components: companion preprocessor models (i.e., the EPS2x emissions and the MM5 meteorological models), the supporting aerometric and emissions data base, and any other related analytical and numerical procedures used to produce modeling results;

> **Model Acceptance is a Continuing Process of Non-Rejection.** Over-reliance on explicit or implied model "acceptance" criteria should be avoided. This includes EPA’s performance goals both for 1-hr and 8-hr modeling. Models should be accepted gradually as a consequence of successive non-rejections. Over time, confidence in a model builds as it is exercised in a number of different applications (hopefully involving stressful performance testing) without encountering major or fatal flaws that cause the model to be rejected;

> **Criteria for Judging Model Performance Must Remain Flexible.** The criteria for judging the acceptability of model performance should remain flexible, recognizing the challenging requirements of the San Juan EAC application including the use of: (a) a nested regional model (CAMx), (b) new emissions data sets developed by the NMED, and (c) prognostic model output (MM5) at nested physical scales cascading down from 36 km to 4 km; and

> **Previous Experience Used as a Guide.** Previous photochemical modeling experience serves as a primary guide for judging model acceptability. Interpretation of the CAMx modeling results for each episode, against the backdrop of previous modeling experience,

will aid in identifying potential performance problems and suggest whether the model should be tested further or rejected.

These principals guided the MM5 model evaluation for all four San Juan Episodes as reported previously by Tesche et al., (2003b). In this chapter we present CAMx model evaluation within the same philosophical framework for both 1-hr and 8-hr ozone concentrations.

3.1.2 Data Supporting Photochemical Model Evaluation

Hourly surface observations of ozone, NO, NO_2, and CO were obtained from the EPA's AQS data base. Over the 36 km grid domain (see Figure 3-1), data from a total of 390 monitoring stations were used in evaluating the model's 1-hr and 8-hr ozone performance. On the 12 km and 4 km grids, the number of ozone monitors was 95 and 17, respectively. Within the 4km domain, the number of monitoring stations reporting NO, NO_2, and CO were 2, 5, and 5 respectively. Within the San Juan Basin (a smaller region of the 4 km domain focusing on just the Four Corners area), no CO data were available and there were only two NO monitors (Bondad and Ignacio). NO_2 monitoring data were available at four monitors (Bondad, Ignacio, Substation, and Bloomfield). No ambient monitoring of volatile organic compounds (VOCs) either speciated or total mass was available within the 4 km modeling domain and there were no airborne data collection programs over the San Juan Basin on any of the days modeled.

3.1.3 Statistical and Graphical Evaluation Tools

The CAMx performance evaluation entailed calculation and analysis of numerous statistical measures of model performance and the plotting of specific graphical displays to elucidate the basic performance of the model in simulating atmospheric variables. Table 7-3 in the San Juan EAC protocol identified the suite of statistical and graphical procedures that were used to evaluate the model. These statistical measures and graphical displays were produced with Alpine's Model Performance Evaluation, Analysis, and Plotting Software (MAPS) system (McNally and Tesche, 1994) recently adapted to include the EPA's 8-hr ozone evaluation recommendations. In this report, we present only the highlights of the CAMx ozone performance evaluation using the MAPS software. However, the full suite of statistics and graphics are contained on the CD's submitted together with this final report.

3.2 Photochemical Model Evaluation Process

The CAMx performance evaluation followed the general procedures recommended in the EPA guidance documents (EPA, 1991; 1999). The evaluation was carried out in two sequential phases, beginning with the simplest comparisons of modeled and observed ground-level ozone concentrations, progressing to complimentary analyses where feasible (e.g., examination of NO, NO_2 and CO precursor species). This evaluation was conducted using the MAPS software routines. Appendix A of the San Juan modeling protocol defines the statistical and graphical procedures used in MAPS for the photochemical model evaluation.

3.2.1 Initial Screening and Diagnostic Analyses

The initial screening evaluation (Phase I) of the CAMx base case ozone predictions was performed for all four (4) modeling episodes in an attempt to identify obviously flawed model simulations and to implement improvements to the model input files in a logical, defensible manner[1]. The graphical displays developed for the initial CAMx simulation of each episode included:

> Spatial mean ozone time series plots;
> Ozone time series plots;
> Ground-level ozone isopleths;
> Ozone concentration scatterplots;
> Bias and error stratified by concentration; and
> Bias and error stratified by time.

This screening was intended to identify obviously flawed simulations and to suggest areas of potential model performance improvement.

The initial CAMx simulations exhibited a systematic tendency toward underestimation of 1-hr ozone concentrations, a common characteristic of the first attempt at a new modeling episode. Accordingly, for all four episodes we undertook diagnostic efforts to improve model performance (i.e., to reduce the discrepancies between model estimates and observations). As stipulated in the protocol, the following principals governed this model performance improvement process:

> Changes to the photochemical model or its inputs must be documented;

> Changes to the model or its inputs must be supported by scientific evidence, analysis of new data, or by re-analysis of the existing data where errors or misjudgments may have occurred;

> All significant changes to the model or its inputs should be reviewed by the project sponsors and/or other advisory group(s).

A series of diagnostic model tests were performed with CAMx examining the role of initial and boundary conditions (ICs/BCs) and anthropogenic emissions. To begin, we found that the boundary conditions used as input to the initial CAMx runs were systematically too low. This finding was based in part upon recent research in the southwestern U.S. (Katzenstein et al., 2003) indicating that light alkane hydrocarbons (largely from oil and natural gas sources) are present in the southwest in far greater quantities than heretofore estimated. Our initial lateral boundary values were purposefully chosen at a 'clean air' level to avoid 'driving' the ozone predictions within the 4 km domain by the boundary assumptions. Based on these and other recent studies of ambient VOC and NO_x concentrations and their role in tropospheric ozone (e.g. Tao et al., 2003), we increased the lateral boundary conditions slightly to the levels used in the Denver EAC modeling study (Morris et al., 2003; 2004). Note that Denver EAC modeling focused on largely the same modeling periods as the San Juan EAC.

3.2.1 Refined CAMx Simulations

Based on the CAMx model diagnostic tests and literature reviews (Morris et al., 2003; Katzenstein et la., 2003; Tao et al., 2003) we used the updated boundary conditions values listed in Table 3-1 in the second round of CAMx model simulations. Note that these values only applied on the lateral boundaries of

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[1] Results of these screening simulations were published in a PowerPoint presentation entitled "San Juan Early Action Compact [EAC] 8-hr Ozone Modeling: CAMx Diagnostics: Round 1"submitted to the NMED on 12 December 2003 as the Task 5.1 Progress Report No. 1.

the 36 km domain shown in Figure 3-1. Boundary values for the inner 12 k and 4 km grids were provided by their outer nests. For boundary conditions aloft (i.e. at ~7000m), we replaced the 'clean air' values with more realistic ozone episode concentrations derived from recent global photochemical model simulations over the U.S. (Martin et al., 2003) derived from the Goddard Earth Observing System Chemistry (GEOS-CHEM) model (Bey et al., 2001). These aloft boundary conditions were used in a manner consistent with our other ongoing ozone modeling studies in California (Tesche, 2003a) and the VISTAS regional haze study (Tesche, 2003b). Table 3-2 presents the aloft boundary conditions derived from the GEOS-CHEM model output.

The second major area where refinements were made to the CAMx inputs was emissions. The internal quality assurance (QA) activity on the biogenic and anthropogenic emissions inventories by ENVIRON and Alpine staff identified a few instances where the initial emissions estimates for some sources or source categories were in error. These discrepancies were resolved and updated base case emissions files for biogenic and anthropogenic sources were developed and used in subsequent CAMx simulations.

With the updates to the initial and boundary conditions and emissions inventory corrections, CAMx was rerun for San Juan Episode 1 and the screening performance evaluation repeated[2]. The updated CAMx ozone results no longer revealed obvious, significant performance problems. Having achieved a reasonable level of model performance with Episode 1, we ran CAMx for Episodes 2 through 4 in a "hands-off" mode. That is, we used the same modeling procedures and assumptions for Episodes 2 through 4 as we had in achieving the Episode 1 final base case. This approach was taken to avoid "tuning" the model to each specific episode. Accordingly, the formal operational evaluation (Phase II) was carried out for all four episodes. This evaluation is discussed next.

3.3 Model Evaluation Results

Consistent with the San Juan protocol, we carried out a detailed performance evaluation of the final CAMx base cases using the revised initial and boundary conditions and emissions inputs described above. Details of the evaluation results are presented in three PowerPoint presentation files:

> "San Juan 8-hr Ozone EAC Study: Model Performance and Future Year Ozone Levels: Executive Summary", submitted to the NMED on 14 January 2004;

> "San Juan 8-hr Ozone EAC Study: Model Performance and Future Year Ozone Levels", submitted to the NMED on 14 January 2004;

> "San Juan 8-hr Ozone EAC Study: Model Performance and Future Year Ozone Levels: Appendix A: CAMx Base Case 1-hr Model Performance Results", submitted to the NMED on 14 January 2004;

These results were presented to the San Juan EAC Technical Peer Review Committee and to the public workshop on 14 January 2004 in Farmington, NM. In addition, the full set of base year (2002) CAMx model evaluation results for all four (4) episodes are contained on the CDs submitted as part of this Task

[2] Results of the refined CAMx simulations were published in a PowerPoint presentation entitled "San Juan Early Action Compact [EAC] 8-hr Ozone Modeling: CAMx Diagnostics: Round 2"submitted to the NMED on 19 December 2003 as the Task 5.1 Progress Report No. 2.

5.1/Task 5.2 Final Report. These evaluations were performed for all species (ozone, NO, NO2, NOx, CO) across four grid domains: 36km, 12 km, 4 km, and the 4 km Four Corners analysis domain. Accordingly, we do not repeat all of these evaluation results here. Instead, we focus on the key ozone model evaluation findings at the five regulatory monitoring stations in the 4 km Four Corners analysis domain. These include the Substation and Bloomfield monitors in San Juan County, the Bondad and Ignacio monitors in La Plata County, CO, and the Mesa Verde monitor in Montezuma County, CO.

3.3.1 Analysis of 1-hr Ozone Results

Following EPA 1-hr ozone modeling evaluation guidance, we produced various graphical products including spatial maps of predictions and observations, scatter and Q-Q plots, and time series plots at each monitoring station across the 36 km, 12 km, and 4 km domains for all pollutant species for which measurements were available. We also generated spatial mean time series plots which present average modeled and observed ozone values on an hourly basis throughout the domains of interest for all four episodes. We calculated the requisite EPA ozone statistical measures including: (a) unpaired (in time and space) peak prediction accuracy, (b) mean normalized bias, and the (c) mean normalized gross error. These statistics were also calculated using all available ozone, NO, NO2, NOx and CO measurements. All of these evaluation products were archived on the CDs. Prominent results from these statistical and graphical analyses were included in the PowerPoint presentations identified in the preceding section.

Table 3-3 presents the 1-hr ozone statistics for the fifteen (15) high ozone days during the four San Juan modeling episodes. For peak prediction accuracy (Au), mean normalized bias (N. Bias), and the mean normalized gross error (N. Error), the statistics were based on the four-cell weighted average of the four cells nearest (and containing) the ozone monitor. In Table 3-3, days for which the accuracy, bias and error fall within the EPA performance goals are highlighted in green. Where the statistics fall outside of the recommended ranges, the day is highlighted in salmon color. Comparison of CAMx base cases with EPA 1-hr ozone goals on a day-by-day basis in the Four Corners analysis region revealed:

> **<u>Unpaired Accuracy of Peak Prediction</u>**: The EPA goal [$\pm$ 15-20%] was achieved on all15 modeling days achieve the goal, most by a wide margin;

> **<u>Mean Normalized Bias</u>**: The EPA goal [$\pm$ 5-15%]: was achieved on 10 of the 15 modeling days while three of the five days missing the goal were on the outer cusp of the range; and

> **<u>Mean Normalized Gross Error</u>**: The EPA Goal [< 30-35%] was passed on all 15 modeling days by a wide margin.

Synthesizing the full set of 1-hr ozone performance results, across all four episodes and all three grid scales (36/12/4 km) the CAMx model produced 1-hr ozone model performance that was well within EPA performance goals in all but a few cases. The San Juan EAC results for 1-hr ozone concentrations are, in our experience, better than that typically encountered in a ‘first time application’ of a photochemical modeling system to a new region. Where the modeling system shows performance difficulties, they are largely consistent with known opportunities for data base improvements (e.g., area source emissions, on-road motor vehicle emissions) in the local area (Four Corners) and surrounding region (western U.S.). The main concern with the four (4) San Juan base cases from a regulatory standpoint is the systematic tendency to underestimate ozone concentrations at some monitoring locations. However, this feature was also evident in other independent, corroborative modeling with EPA’s CMAQ model over the western U.S. with the 13-21 July 1999 VISTAS data base (Tesche, 2003b) employing similar emissions and meteorological modeling foundations. Given the generally very favorable 1-hr ozone results, we now turn to an analysis of the 8-hr ozone concentrations.

3.3.2 Analysis of 8-hr Ozone Results

We extended the MAPS evaluation software to calculate some of the more useful performance statistics outlined in the draft EPA 8-hr guidance together with other statistical measures[3] and graphical procedures we believe are helpful in elucidating model performance. Since there is still limited historical experience in calculating and interpreting 8-hr model performance statistics, we examined a number of different metrics based 8-hr averaging times and different procedures for spatial pairing of predictions and observations. We also utilized various graphical display routines to compare and contrast 8-hr model performance with that determined described in the previous subsection.

Draft EPA (1999) guidance suggests that for 8-hr model performance testing, the emphasis should be placed on the bias and fractional bias measures. Here, bias is defined mathematically as the difference (in ppb) between peak 8-hr prediction and observation. The fractional bias (in percent) is simply the bias divided by the mean of the prediction and observation. The key difference in the 8-hr metrics is that instead of taking a bi-linear interpolation of the nearest four grid cells surrounding the monitor (as we did in calculating peak accuracy, normalized bias and normalized error in Tables 3-3 and 3-4), EPA recommends that the fractional bias and fractional error statistics should be based on an analysis of the model predictions in the nearest 7 x 7 array of 4 km grid cells surrounding the monitor, i.e., the "neighborhood" (EPA, 1999, pg. 38).

Furthermore, the guidance suggests that the <u>maximum predicted value</u> in the 7 x 7 array of grid cells should be selected when making this comparison. However, as was debated extensively by the science team panel assisting EPA in the original development of the draft guidance, selection of the "maximum" model prediction in the 7 x 7 array of grid cells introduces a systematic bias into the assessment of model performance. *Since the objective of the model evaluation is to test the model's ability to reproduce past events, there was no a priori justification for the maximum value.* Indeed, the "mean", "best", "minimum" or other metrics are equally plausible. EPA countered with the view that since the model was to be used in evaluating future year control strategies for which maximum predictions were the focus, it would be simpler to base all prediction-observation metrics on the "maximum" value instead of having one definition for the performance evaluation and another for the control strategy assessment modeling. Consensus was never achieved on this point, in part because there was no community experience in the late 1990s in using any of the proposed 8-hr performance metrics. It was concluded that alternative procedures should be pursued by interested groups active in regulatory modeling and when EPA's final 8-hr guidance was developed, this issue would be revisited in light of newer information on the subject. Accordingly, in this report we choose the 'best' model estimate in the 7 x 7 array of grid cells to compare with observations in the model performance evaluation and we choose the 'maximum' model estimate in the 7 x 7 array of grid cells in the 2002 base case and 2007 future year baseline when calculating the relative reduction factors (RRFs).

Actually, we evaluated the CAMx model's 8-hr performance using all four alternative procedures for deriving the model prediction to be used in the bias and fractional bias measures as well as in the graphical displays. These include the "maximum", "minimum", "best" and "cell" values. The maximum

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[3] This situation will clearly change as the current round of EAC studies is completed and analyzed by EPA and the states.

and minimum values in the 7 x 7 array are self-explanatory. The "best" prediction is the modeled value in the 7 x 7 array that most closely matches the monitored value for that day. The "cell" value is the model prediction in the grid cell in which the monitor resides. Note that all of these statistics are unpaired in time, meaning that the 8-hr time frame corresponding to the maximum observed ozone value may not necessarily correspond exactly to the time span for the minimum, maximum, best, or cell estimate. We also examined the time lags associated with these measures and found for the nine PFOS episodes that in more than 90% of the cases the time lag between the predicted and measured 8-hr maxima was 2 hours or less. The results of this analysis, not discussed further in this report, are contained on the CDs that accompany the report.

Table 3-4 presents the 8-hr ozone statistics for the fifteen (15) high ozone days during the four San Juan modeling episodes. In this table (as well as Table 3-3 presented earlier) we list not only the traditional metrics of peak prediction accuracy (Au), mean normalized bias (N. Bias), and the mean normalized gross error (N. Error), but also present the fractional bias (FB) and fractional error (FE) statistics that figure prominently in EPA's draft 8-hr guidance document. In Table 3-4, days for which the unpaired peak accuracy, normalized bias, normalized gross error, fractional bias and fractional error fall within the EPA performance goals are highlighted in green. Where the statistics fall outside of the recommended ranges, the day is highlighted in salmon color. Comparison of CAMx base cases with EPA 8-hr ozone goals on a day-by-day basis in the Four Corners analysis region revealed:

> Bias in daily maxima 8-hr predictions and observations over several days: The bias in daily maximum 8-hr predictions over the 15 episode days is below EPA's goal [<20%] on 91% of the modeling days:

> Fractional bias in daily maxima 8-hr predictions and observations over several days: The fractional bias in daily 8-hr predictions over the 15 episode days is below EPA's goal [<20%] on 83% of the modeling days;

> Bias in 8-hr daily maximum and 1-hr daily average over all monitors: Bias for 8-hr and 1-hr predictions are 3.6% and –11.9%, easily meeting the EPA goal of [<15%].

> Gross error in 8-hr daily maximum and 1-hr average over all monitors: Gross errors for 8-hr and 1-hr predictions are 20.9% and 21.5%, easily meeting the EPA goal of [30-35%];

> Scatter plots and Q-Q plots of 8-hr and 1-hr concentration distributions: Scatter plots and Q-Q plots do not exhibit spurious, obviously flawed trends; and

> Correlation coefficients based on all predictions-observations, paired in time and space: For photochemical models, we have not found the correlation coefficient to provide useful information in model testing (Tesche et al., 1990). However, the 8-hr and 1-hr variance measures (131.0 ppb and 164.0 ppb) are somewhat useful in comparing model simulations and in the case of the San Juan episodes are acceptably small.

To facilitate the comparison of the 8-hr and 1-hr ozone statistics presented in Tables 3-3 and 3-4, we present histograms in Figure 3-2 thorough 3-8 that depict graphically the daily variation in these metrics.

Figure 3-9 presents the daily maximum 8-hr modeled ozone concentrations for each day of Episode 1 on he 4 km grid. The solid numerals in the figures represent the observed 8-hr maximum ozone concentrations at the various monitors. The statistics at the top of each page identify the maximum, minimum, average, and grid total 8-hr ozone concentrations predicted by CAMx over the 4 km domain. Similar plots for 1-hr and 8-hr ozone for all four episodes have been produced and analyzed but they are not presented here. We have found that in examining the results for Episode 1, that very similar features are seen in the results for Episodes 2 thorough 4. Thus, the Episode 1 results give a good indication of that the other modeling days reveal as well. Of course, the graphics for all days on all grids have been archived on CD for readers interested in exploring specific days in further detail. It is quite apparent from examination of the 8-hr ozone concentration results in Figure 9 that the maximum concentrations across the majority of the Four Corners domain during Episode 1 are in the 50-70 ppb range. The daily maximum 8-hr ozone predictions across the region for the five days ranges between 64.5 ppb and 75.8 ppb. Note that the maximum value in Episode 1—75.8 ppb, occurred over the Grand Canyon in Arizona. The peak on this day (7 June 2002) over the Four Corners region was in the 60-65 ppb range.

Figures 3-10 through 3-13 present time series plots of the spatial mean 1-hr and 8-hr ozone concentrations for all four San Juan episodes using the "best" estimate of the model in each 7 x 7 neighborhood. In these plots the solid line corresponds to the average ozone concentrations across the five monitors in the San Juan Analysis Domain (Bondad, Ignacio, Substation, Bloomfield, and Mesa Verde). The asterisks represent the corresponding average measurements. From the figures we see that there is greater variation in the 1-hr time series compared with the 8-hr time series as expected. Also, examination of the 1-hr and 8-hr time series plots generated wit the "best" versus "maximum" concentrations from the 7 x 7 grid arrays surrounding each monitor does not appreciably change the plot. The basic features between the modeled and observed times series are similar. The greatest differences occur at night where the "maximum" grid cell method exhibits the greater bias of the two methods.

Overall, the 8-hr spatial mean plots exhibit better agreement with observations compared with the 1-hr plots. Part of this is due no doubt to the fact that averaging over the 8-hr time interval and especially using the "best" model estimate in the 7 x 7 neighborhood tend to produce better correspondence with observations. Nonetheless, examination of Figures 8-4 and 8-5 reveal that the model does better for some episodes and poorer for others. The best correspondence between spatial mean observations and the "best" and "mean" cell predictions—particularly for the afternoon peaks--occur for Episodes 1, 3, 5, and 9. The poorest afternoon spatial mean performance occurs for Episodes 2 and 8. Note that for some episodes, the model does well for one day and then under-performs for the following day (see, for example, 24-25 April 1998 (Episode 8).

8-hr ozone time series are shown in Figure 3-14 for the five stations in the Four Corners analysis domain for Episode 1. Perusal of the time series plots at these stations for the other three episode reveals similar features so only the Episode 1 results are presented here. These results show a recurring theme for all four episodes. Hourly and 8-hr ozone concentrations at the New Mexico stations (i.e., Bloomfield and Substation) tend to be underestimated while at the northerly, higher elevation sites in southern Colorado (e.g. Bondad and Ignacio), the model tends to overestimate values. At the remote Mesa Verde site, the ozone time series exhibits typical 'background' monitor behavior. The most plausible explanation for the systematic underestimation at the Bloomfield and Substation monitors seems to be the fact that these two sites, located in the San Juan/Animas river drainages near the cities of Bloomfield and Farmington may be subject to local ozone-NO titration chemistry due to local NO emissions from traffic and fuel combustion sources. The Ignacio and Bondad sites are much less influenced by local sources and would therefore not be expected report ozone levels depressed by NO titration.

Finally, Figure 3-15 shows examples of quantile-quantile plots of predicted and observed 8-hr ozone concentration distributions during the middle of Episode 1. These Q-Q plots are typical of the full set of plots contained on the CD, although on some days, the distributions show greater or lesser over and/or underprediction across different subregions of the concentration ranges. Examination of the 1-hr and 8-hr Q-Q plots for all episodes reveals no significant biases or problems in the CAMx simulations of these base cases.

3.4 Assessment

The CAMx 8-hr ozone performance results exhibit a level of performance for all four episodes that was well within EPA's draft performance goals in all but a few cases. The results are quite consistent with model applications in other regions and are typically better than that encountered in a 'first time application' of a photochemical modeling system to a new region. With respect to the adequacy of the CAMx modeling and the suitability of the current base cases, we conclude that:

> The San Juan photochemical modeling activity clearly selected an appropriate regional photochemical model for use in this assessment;

> The CAMx modeling was carried out in a credible, well-documented manner that was consistent with current practice in regional photochemical modeling and the procedures commonly used in the application of this sophisticated model;

> The suite of evaluation procedures employed to test the CAMx model were comprehensive and consistent with EPA's recommended methods for both 1-hr and 8-hr ozone modeling;

> The data base available to test the CAMx model was extremely limited, precluding a number of meaningful, stressful tests of the model to ascertain whether it suffers from internal, compensating errors; as a result, model testing was largely confined to an operational evaluation of hourly-average, ground-level ozone concentrations;

> Generally, the CAMx performance for surface 1-hr and 8-hr ozone concentrations are quite consistent with contemporary modeling experience and with EPA's suggested 8-hr ozone evaluation benchmarks;

> None of the performance testing results conducted have revealed flaws in CAMx performance of such a magnitude as to clearly indicate the presence of errors that would render the model inappropriate for use, with proper cautions, in evaluating future year 8-hr ozone attainment or generalized emissions control scenarios.

The CAMx bases cases for Episodes 1 through 4 may be used, with appropriate cautions, to evaluate year 2007 baseline conditions, to examine model sensitivity to plausible VOC and/or NOx emissions reduction strategies, and to demonstrate attainment with the 8-hr ozone NAAQS.

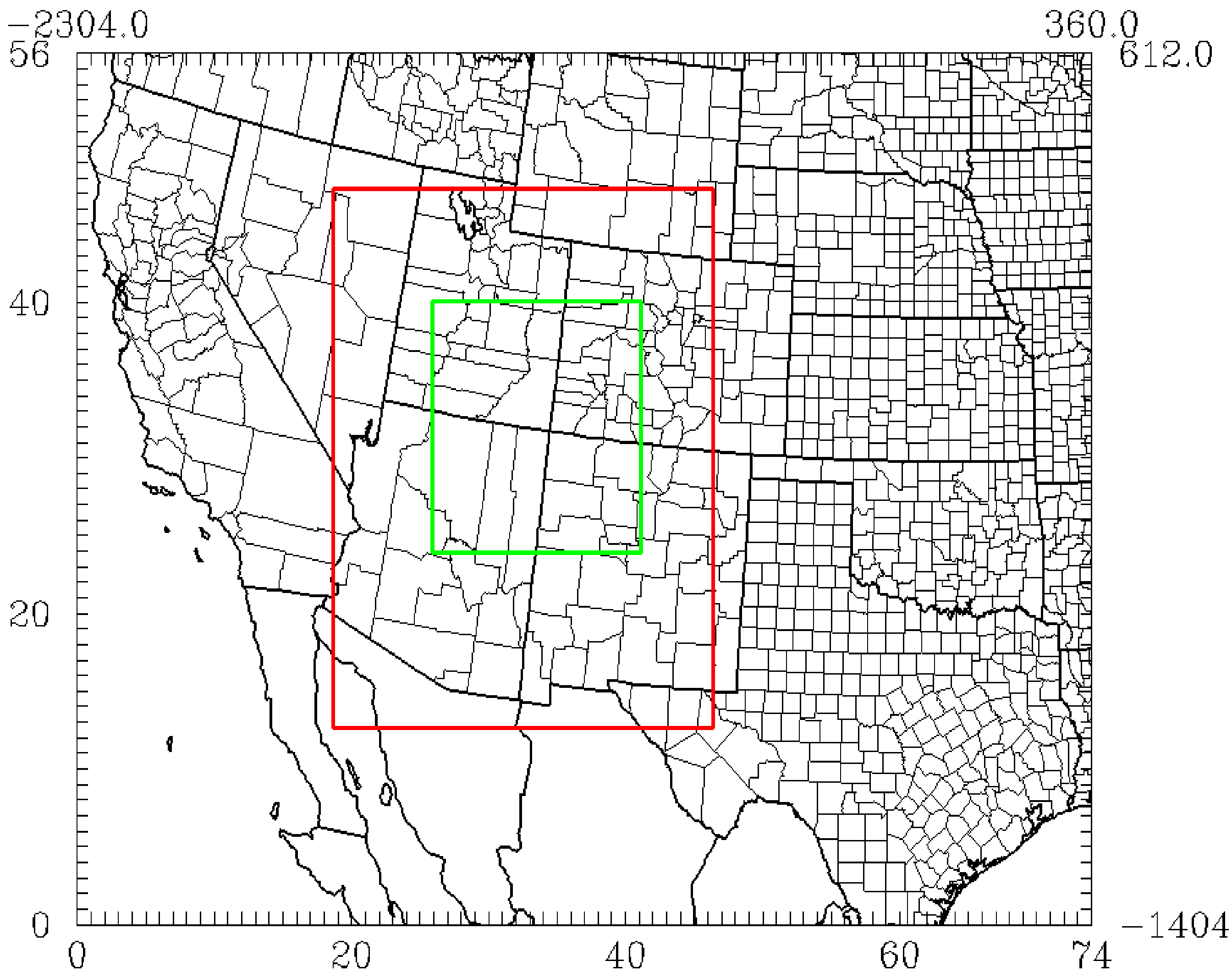


Figure 3-1. Location of the Three Grid Nests Used in the CAMx 1-hr and 8-hr Ozone Model Performance Evaluation (Outer Grid is 36 km; inner nests are 12 km and 4 km, respectively).

Table 3-1. Lateral Boundary Conditions Used in the San Juan/Four Corners Modeling.

Species	Eastern and Northern Boundaries below 1700 m (ppb)	Southern Boundary Below 1700 m (ppb)	Western Boundary and Above 1700 m (ppb)
O3	40.0	40.0	40.0
NO	0.1	0.1	0.1
NO2	1.0	1.0	1.0
CO	200.0	200.0	100.0
PAR	14.9	14.9	14.9
HCHO	2.1	2.1	0.05
ETH	0.51	0.51	0.15
ALD2	0.555	0.555	0.05
TOL	0.18	0.18	0.0786
PAN	0.1	0.1	0.1
HNO2	0.001	0.001	0.001
HNO3	3.0	3.0	1.0
H2O2	3.0	3.0	1.0
OLE	0.3	0.3	0.056
XYL	0.0975	0.0975	0.0688
ISOP	3.6	0.1	0.001
MEOH	8.5	0.001	0.001
ETOH	1.1	0.001	0.001
Total NOx	1.1	1.1	1.1
Total VOC (ppbC)	50.5	22.3	9.3

Table 3-2. Top Boundary Conditions Used in the San Juan/Four Corners Modeling.

Species	Conc (ppb)	Species	Conc (ppb)	Species	Conc (ppb)
NO	0.001132	PNA	0.002902	CG2	0.00173
NO2	0.0005182	PAN	0.08779	CG3	0.0004481
NXOY	0.0004602	CO	64.59	CG4	0.01154
O3	61.4	HONO	0.000006343	PNO3	2.461
FORM	0.06908	H2O2	0.7944	POA	4.29
ALD2	0.02536	HNO3	0.123	PEC	1.12
ETH	0.001219	NTR	0.06421	PSO4	86.67
OLE	0.0009171	SO2	0.008489	FCRS	5.156
PAR	2.888	SULF	0.00003696	CCRS	8.488
TOL	0.001637	ISOP	0.0006887	PH2O	18.24
XYL	0.0001523	OLE2	0.0000291	PCL	1.821E-23
CRES	0.0004455	NH3	2.019E-10	NA	1.181E-23
MGLY	0.0003117	ISPD	0.006533	PNH4	10.48
OPEN	0.00003109	CG1	0.0006067		

Table 3-3. CAMx 1-hr Ozone Model Evaluation Results for San Juan EAC Episodes 1-4: Four Corners Analysis Domain.

		Four Corners Analysis Region											
Date	Day	ATS	FB	FE	AU	A-MEAN	N. Bias	Bias	N. Error	Error	Var	Max. O	Max. P
04-Jun	155	-30.9	-8.5	12.6	10.1	17.9	-12.4	-7.4	18.0	10.0	97.7	70.0	77.1
05-Jun	156	-29.2	-13.1	14.8	-15.6	18.3	-18.9	-12.1	24.2	14.7	153.7	87.0	73.4
06-Jun	157	-38.6	-5.2	9.9	-9.8	15.5	-6.0	-4.5	17.1	10.2	157.0	78.0	70.3
07-Jun	158	-18.0	5.5	13.8	6.2	17.8	1.8	-0.9	22.2	12.3	233.7	78.0	82.9
08-Jun	159	-27.7	-6.6	14.7	-1.6	20.3	-14.4	-10.7	24.2	15.4	216.5	79.0	77.7
16-Jun	167	-16.4	-5.8	5.9	-0.4	8.3	-8.9	-6.5	18.3	11.1	119.1	78.0	77.7
17-Jun	168	-34.2	-10.6	10.6	2.3	13.7	-7.6	-6.0	17.5	10.8	123.2	87.0	89.0
18-Jun	169	-23.9	-3.6	7.0	18.4	8.8	-4.8	-3.9	18.4	10.8	139.7	79.0	93.5
19-Jun	170	-21.7	-7.9	9.5	4.3	13.3	-8.9	-7.1	19.7	12.8	181.6	80.0	83.4
30-Jun	181	5.8	4.2	4.2	17.4	10.3	-0.9	-1.1	17.6	9.2	136.4	66.0	77.5
01-Jul	182	-21.9	-5.7	5.7	6.9	11.3	-22.2	-12.3	26.2	14.1	154.4	67.0	71.6
02-Jul	183	-34.1	-9.4	9.5	-18.6	14.9	-26.7	-16.7	28.3	17.5	192.5	91.0	74.1
16-Jul	197	-35.9	-3.8	9.5	-3.4	20.6	-13.6	-8.3	23.2	12.8	180.8	76.0	73.4
17-Jul	198	-31.0	-5.7	8.2	-11.6	16.9	-17.9	-10.7	23.8	13.6	174.2	86.0	76.0
18-Jul	199	-23.8	-4.1	5.6	-7.4	11.6	-17.4	-10.5	23.4	13.5	199.5	84.0	77.8
Average		-25.4	-5.3	9.4	-0.2	14.6	-11.9	-7.9	21.5	12.6	164.0	79.1	78.4

Table 3-4. CAMx 8-hr Ozone Model Evaluation Results for San Juan EAC Episodes 1-4: Four Corners Analysis Domain.

		Four Corners Analysis Region											
Date	Day	ATS	FB	FE	AU	A-MEAN	N. Bias	Bias	N. Error	Error	Var	Max. O	Max. P
04-Jun	155	-19.7	-7.2	12.5	7.9	16.4	-14.8	-8.6	21.1	11.4	112.6	65.0	70.1
05-Jun	156	-26.1	-11.4	14.5	-16.1	17.6	-16.0	-10.3	22.3	13.2	113.7	80.6	67.7
06-Jun	157	-21.1	-0.3	9.4	-2.2	14.8	0.7	-1.0	19.2	10.2	137.3	69.9	68.3
07-Jun	158	-23.0	5.7	16.1	-1.8	25.2	1.2	-1.1	21.8	11.6	191.6	77.1	75.8
08-Jun	159	-26.0	-7.2	16.4	-4.3	19.7	-10.6	-8.1	22.0	13.4	159.9	76.8	73.4
16-Jun	167	-19.2	-4.6	9.1	-4.4	14.0	-7.3	-5.3	18.1	10.4	94.8	73.8	70.5
17-Jun	168	-24.5	-7.2	8.7	-2.2	13.0	-7.8	-5.7	17.3	10.4	98.2	80.4	78.6
18-Jun	169	-16.2	-0.1	7.4	11.7	12.2	-1.6	-2.0	17.5	9.8	112.8	75.1	83.9
19-Jun	170	-21.3	-8.1	10.6	-5.0	16.3	-5.5	-4.8	20.7	12.3	145.4	77.5	73.6
30-Jun	181	2.0	6.6	6.8	12.9	11.3	-3.9	-2.7	17.3	8.9	132.5	64.3	72.5
01-Jul	182	-19.1	-8.5	9.5	3.9	13.9	-20.8	-11.4	24.4	13.0	92.2	64.4	66.9
02-Jul	183	-29.1	-11.3	12.2	-16.7	20.1	-19.6	-12.6	21.9	13.7	121.6	78.8	65.6
16-Jul	197	-27.3	-4.1	10.9	-8.7	19.7	-16.5	-9.4	24.0	12.8	155.8	70.3	64.1
17-Jul	198	-19.7	-4.1	9.4	-10.2	17.0	-17.6	-10.6	25.2	14.2	145.9	74.5	66.9
18-Jul	199	-29.0	-5.5	9.7	-15.8	13.6	-12.7	-7.9	20.3	11.5	151.6	79.2	66.7
Average		-21.3	-4.5	10.9	-3.4	16.3	-10.2	-6.8	20.9	11.8	131.0	73.8	71.0

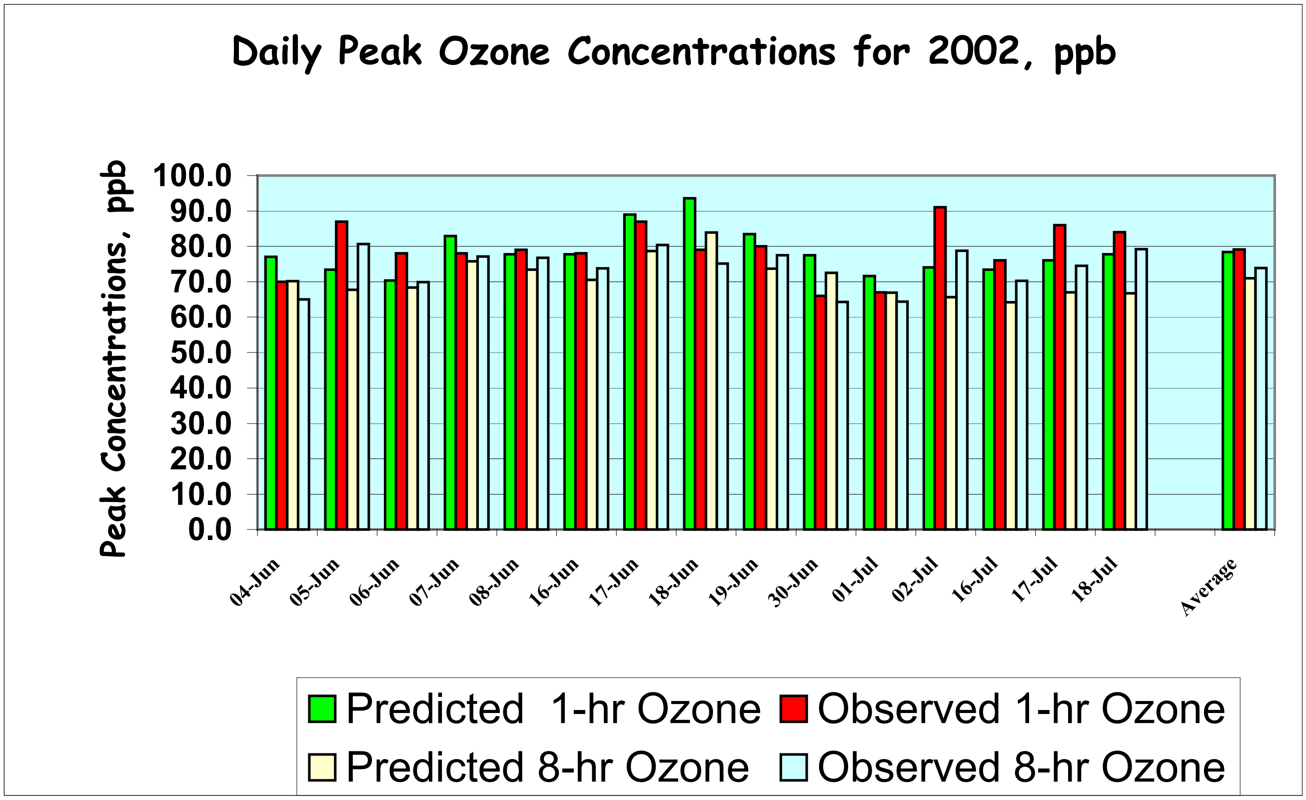


Figure 3-2. **Daily Peak 1-hr and 8-hr Ozone Concentrations Across the Four Corners Analysis Domain.**

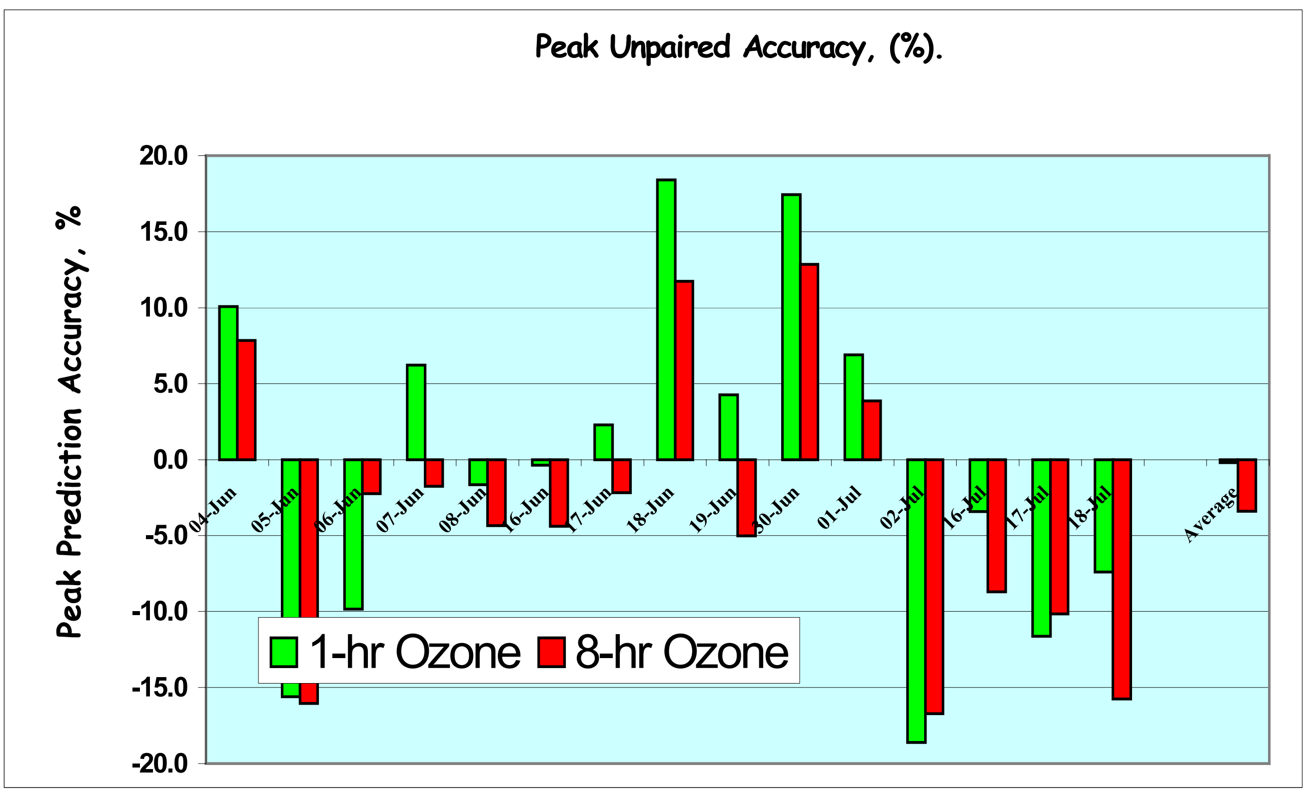


Figure 3-3. **Peak Unpaired Prediction Accuracy for 1-hr and 8-hr Ozone Concentrations Across the Four Corners Analysis Domain.**

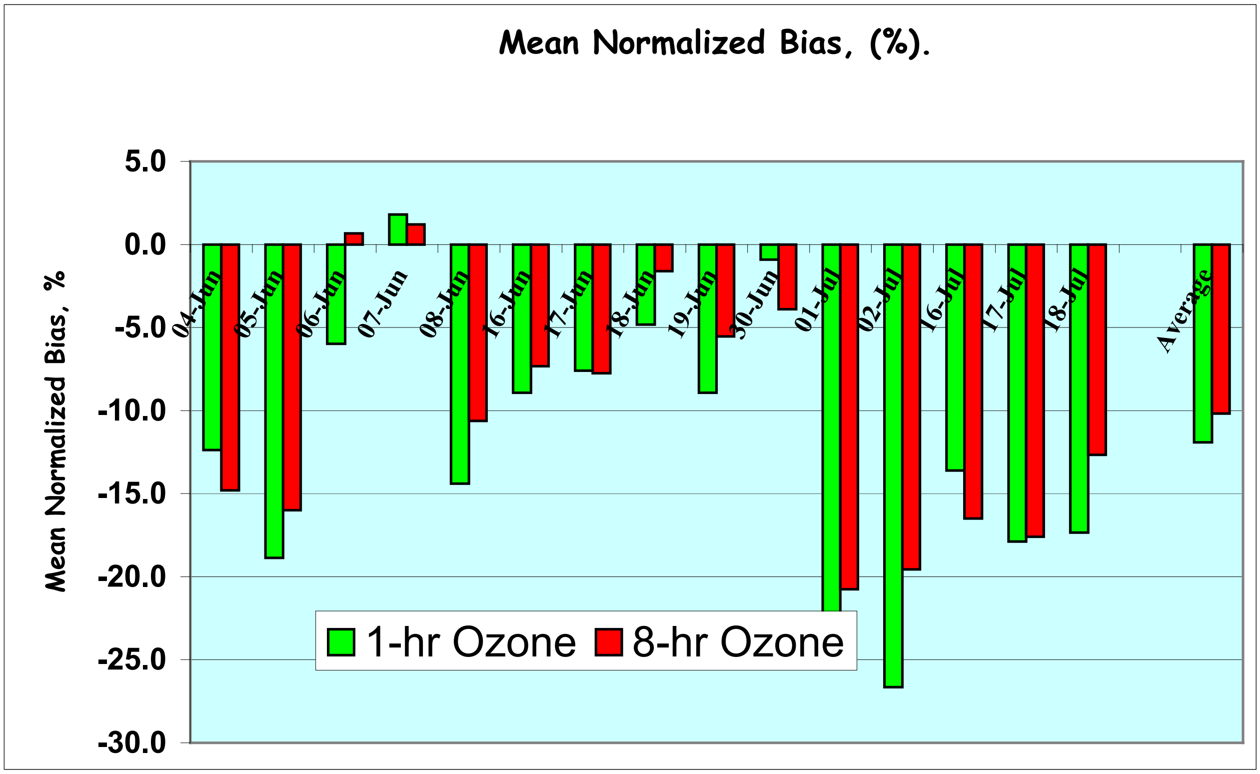


Figure 3-4. **Mean Normalized Bias in 1-hr and 8-hr Ozone Concentrations Across the Four Corners Analysis Domain.**

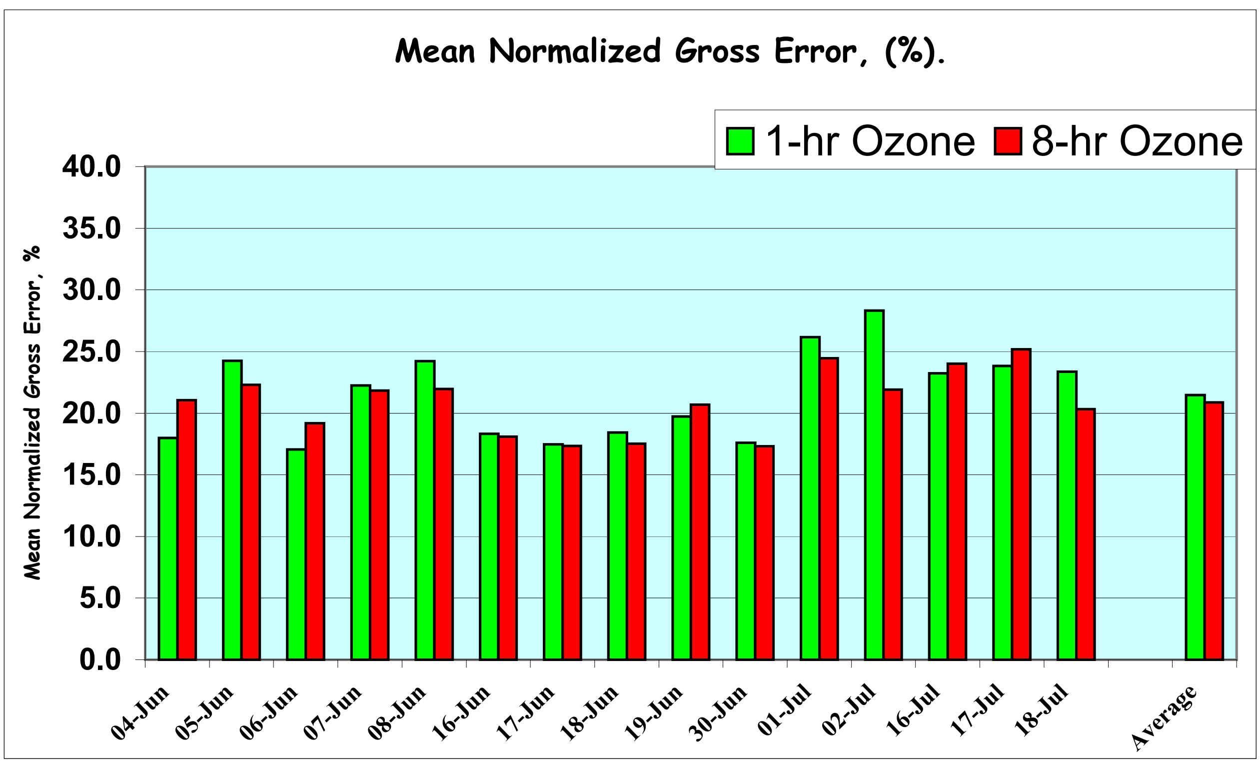


Figure 3-5. **Mean Normalized Gross Error in 1-hr and 8-hr Ozone Concentrations Across the Four Corners Analysis Domain.**

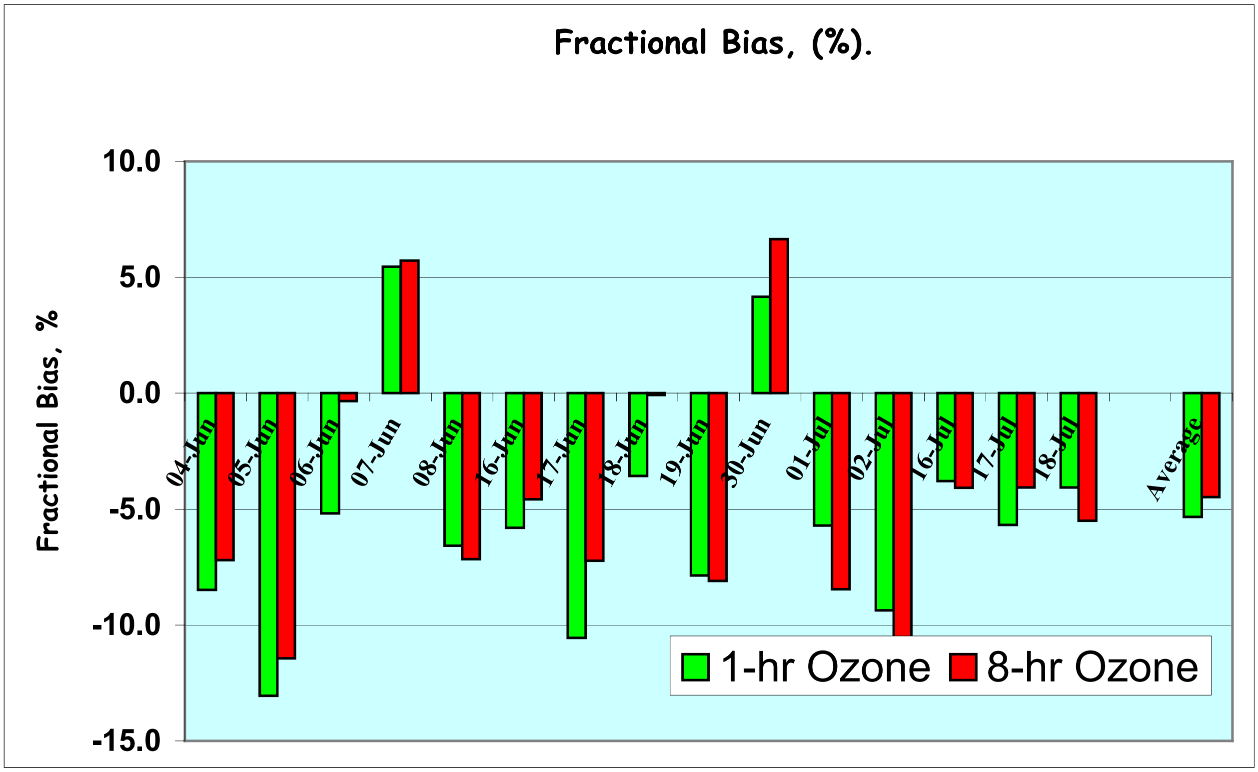


Figure 3-6. Fractional Bias in 1-hr and 8-hr Ozone Concentrations Across the Four Corners Analysis Domain.

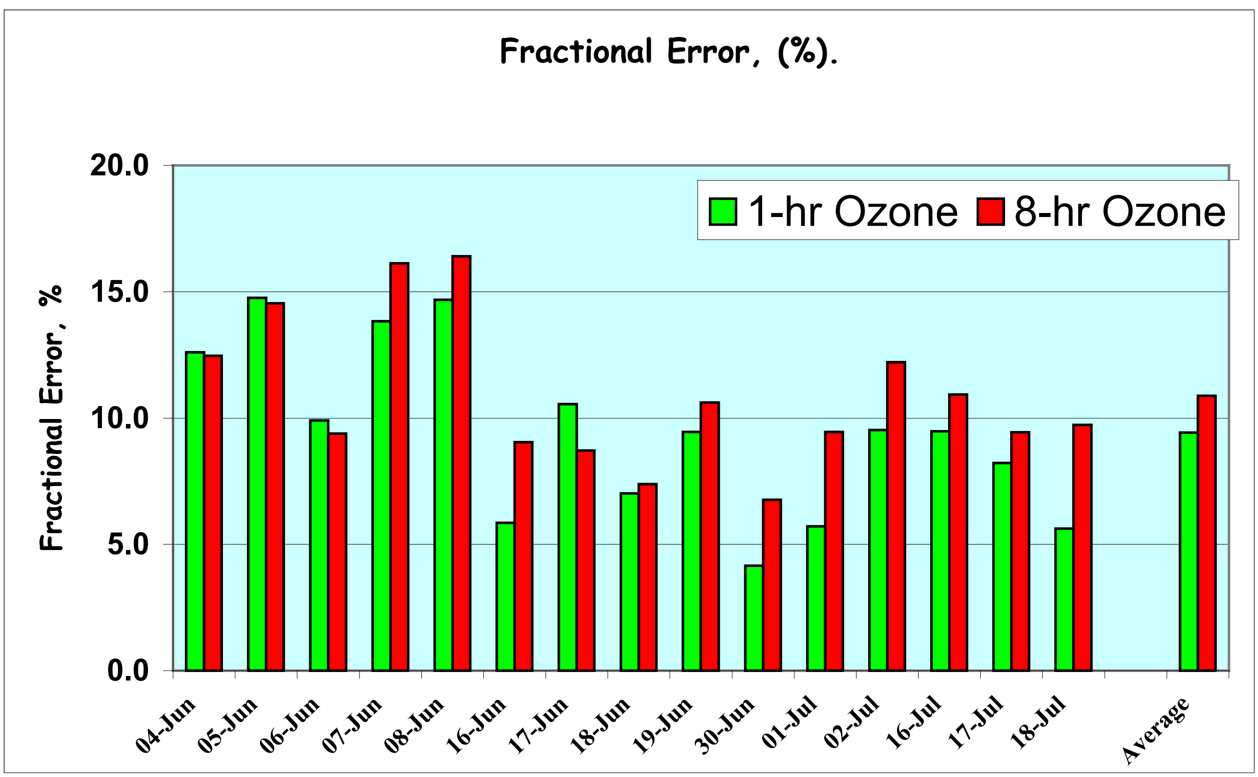


Figure 3-7. Fractional Error in 1-hr and 8-hr Ozone Concentrations Across the Four Corners Analysis Domain.

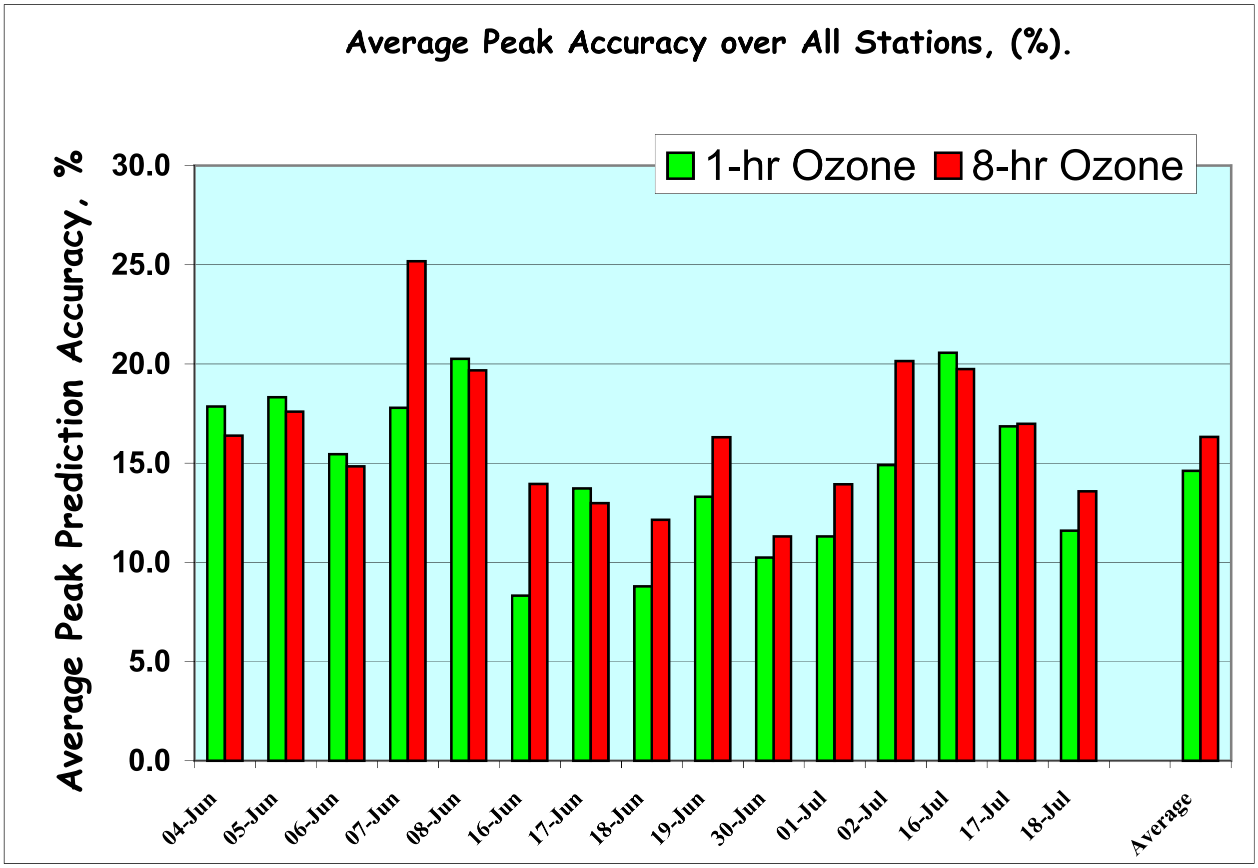
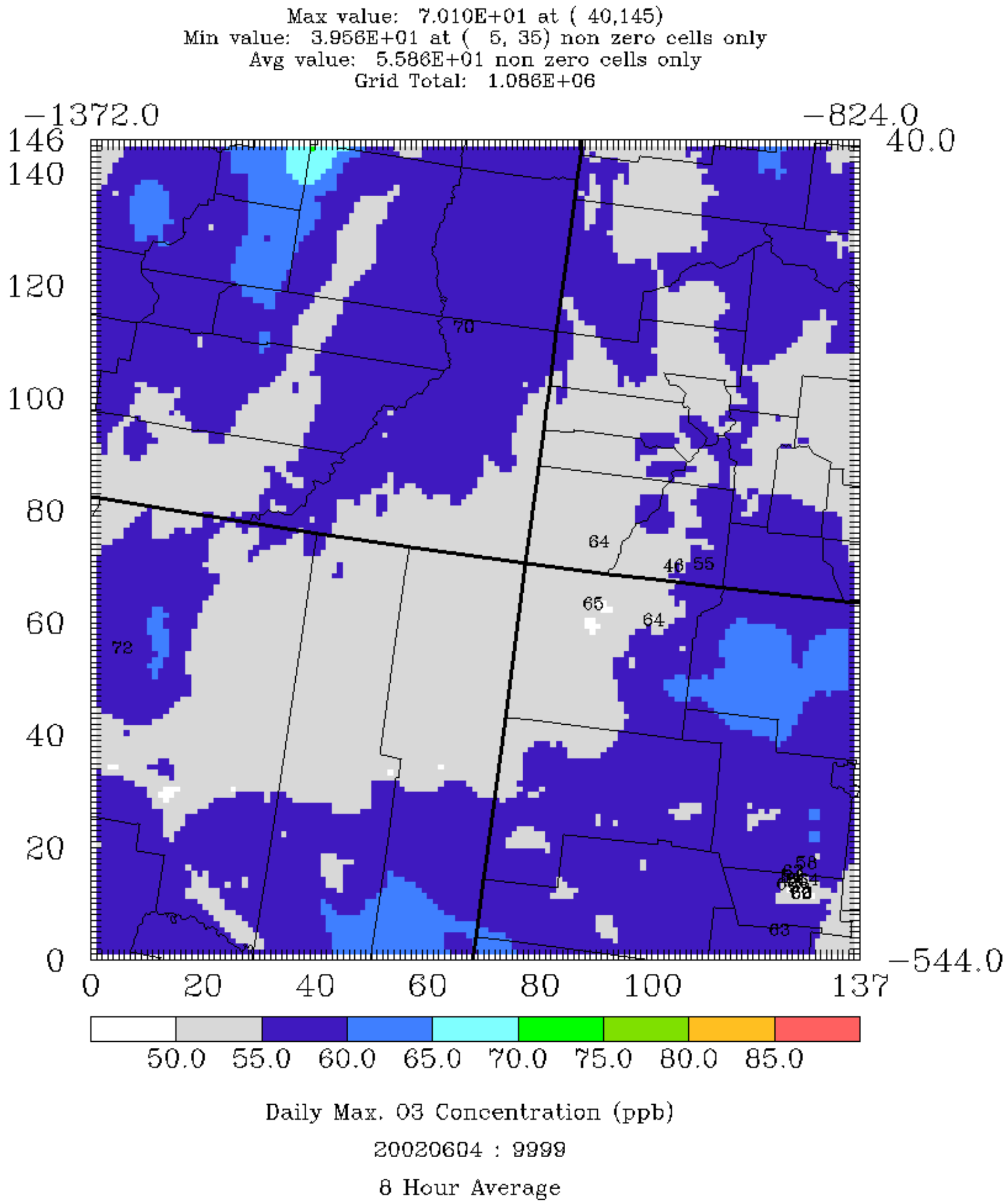
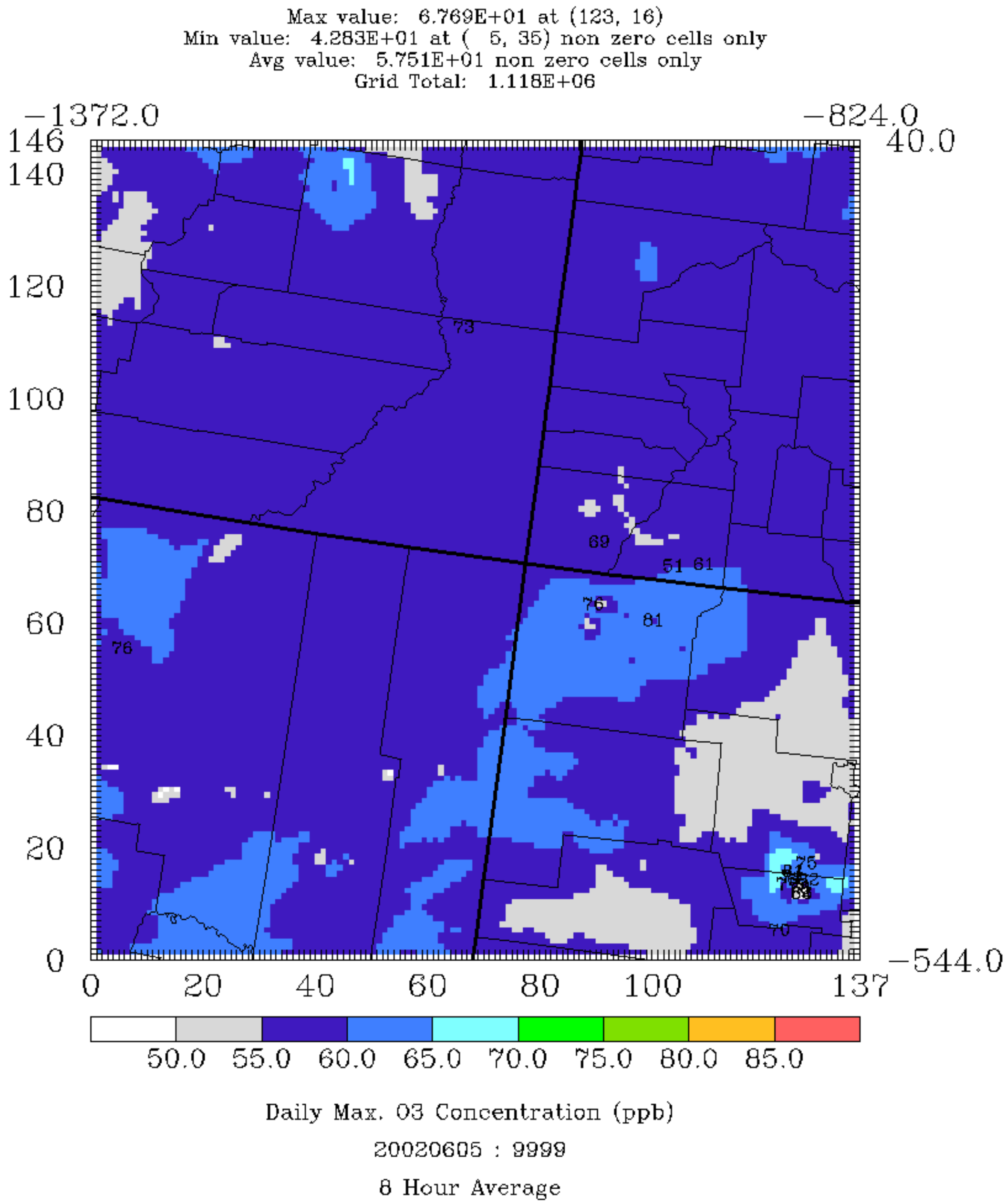


Figure 3-8. Average Peak Prediction Accuracy Over All Monitors for 1-hr and 8-hr Ozone Concentrations Across the Four Corners Analysis Domain.



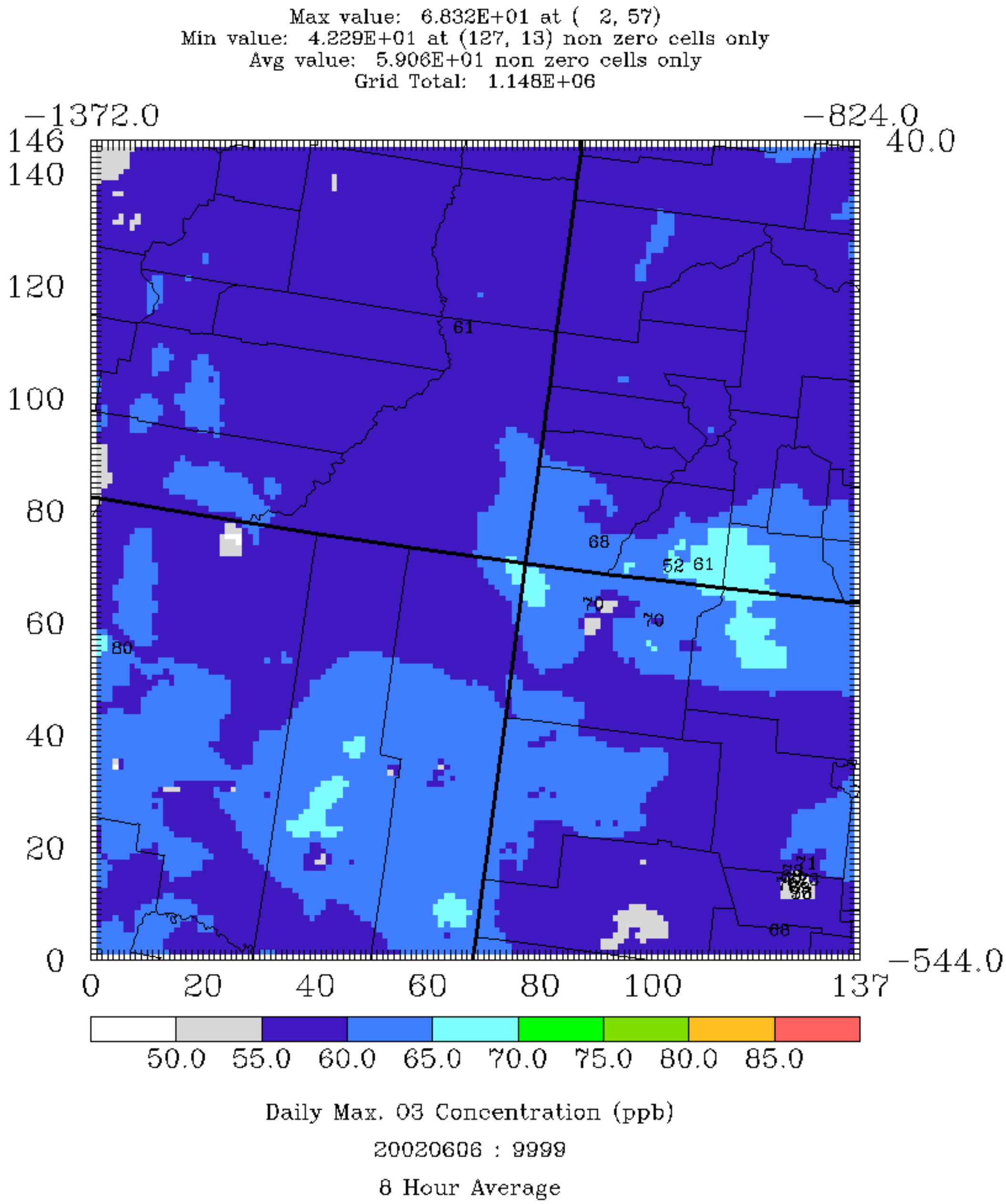
(a) 4 June 2002

Figure 3-9. Daily Maximum Modeled and Observed 8-hr Ozone Concentrations for San Juan Episode 1 Over the 4 km Modeling Domain.



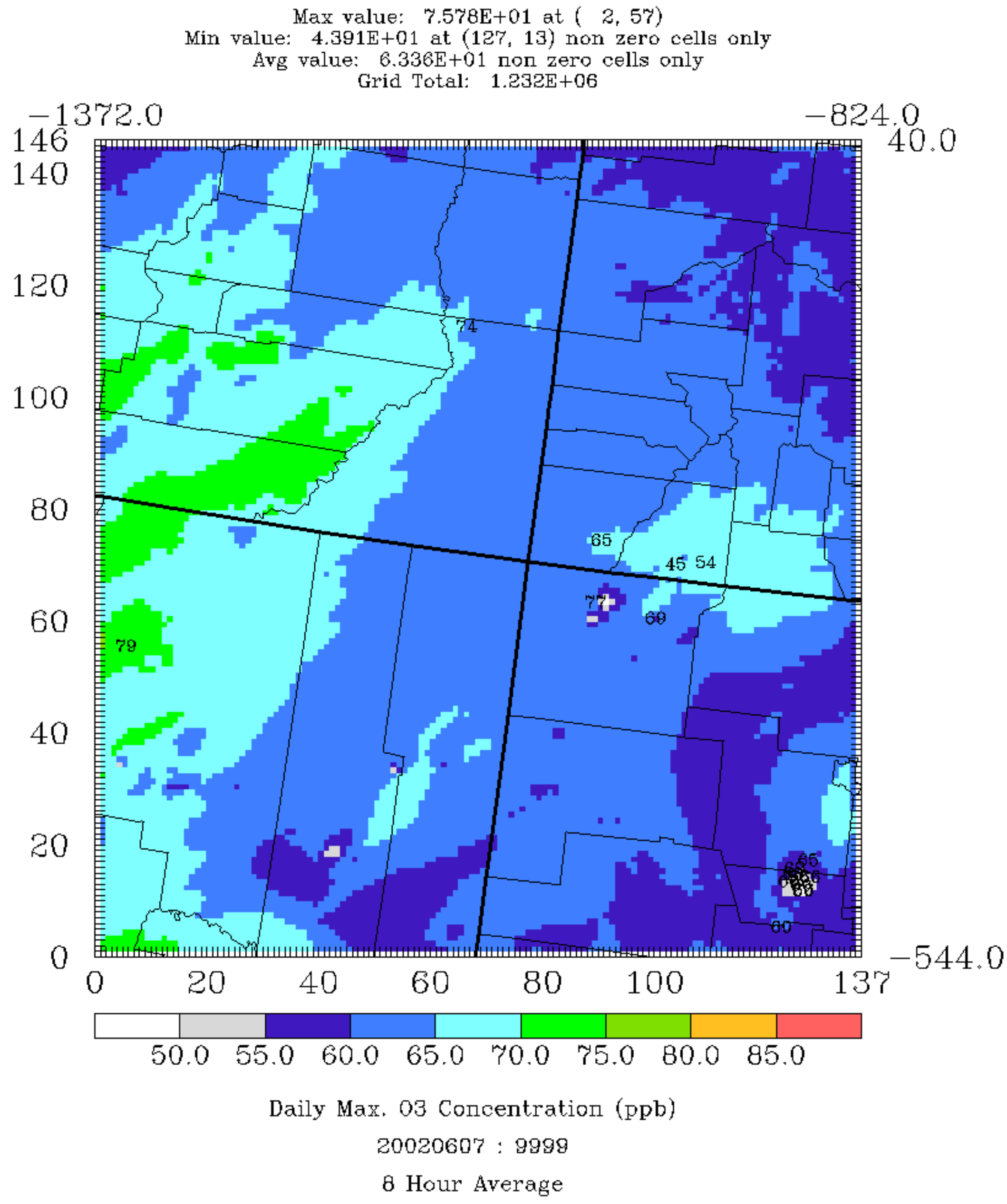
(b) 5 June 2002

Figure 3-9. Continued.



(c) 6 June 2002

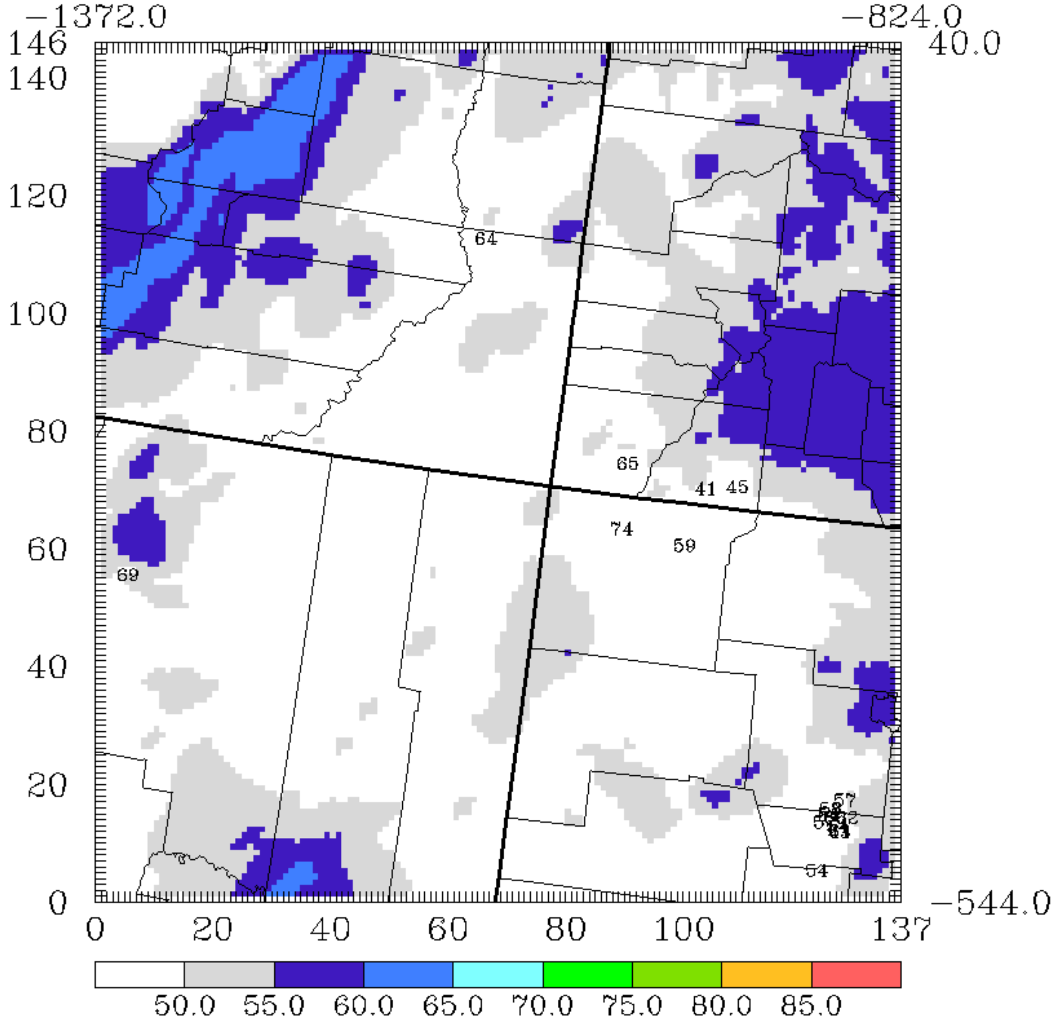
Figure 3-9. Continued.



(d) 7 June 2002

Figure 3-9. Continued.

Max value: 6.449E+01 at (21,126)
Min value: 2.413E+01 at (127, 14) non zero cells only
Avg value: 4.984E+01 non zero cells only
Grid Total: 9.689E+05



O3 Concentration (ppb)
20020608 : 1600
8 Hour Average

(e) 8 June 2002

Figure 3-9. Concluded.

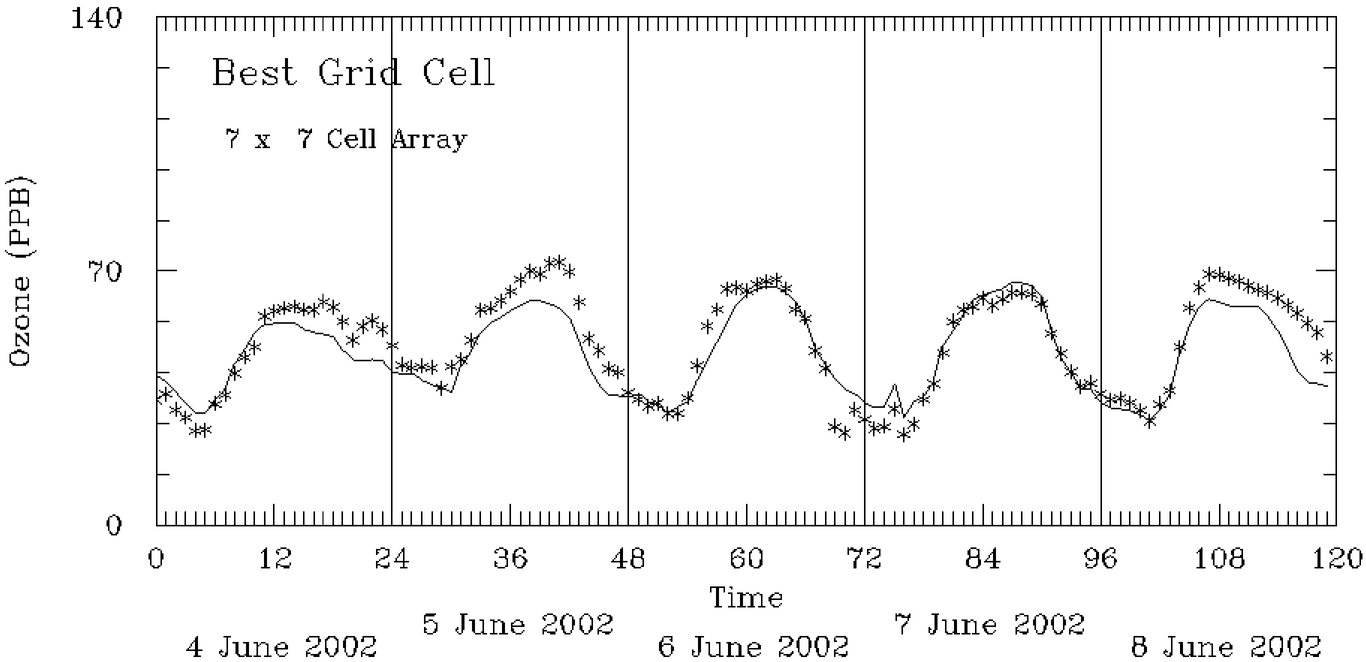


Figure 3-10a. Spatial Mean 1-hr Ozone Time Series Plot for Episode 1.

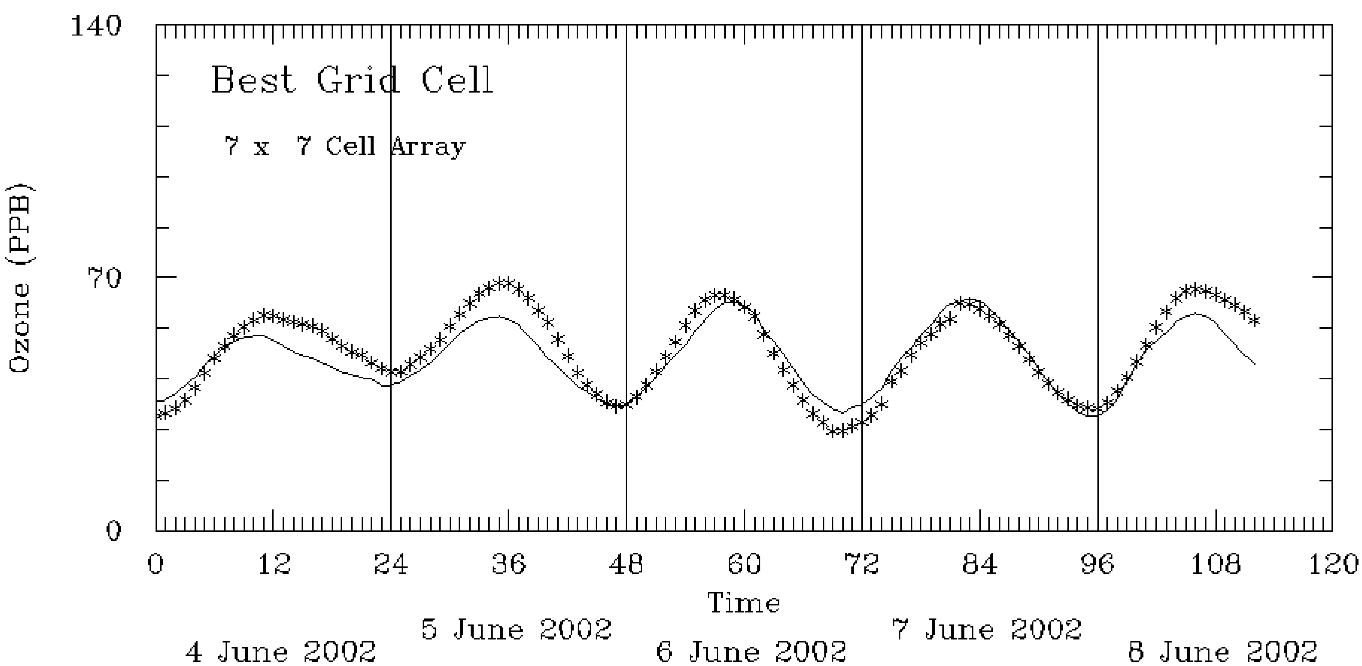


Figure 3-10b. Spatial Mean 8-hr Ozone Time Series Plot for Episode 1.

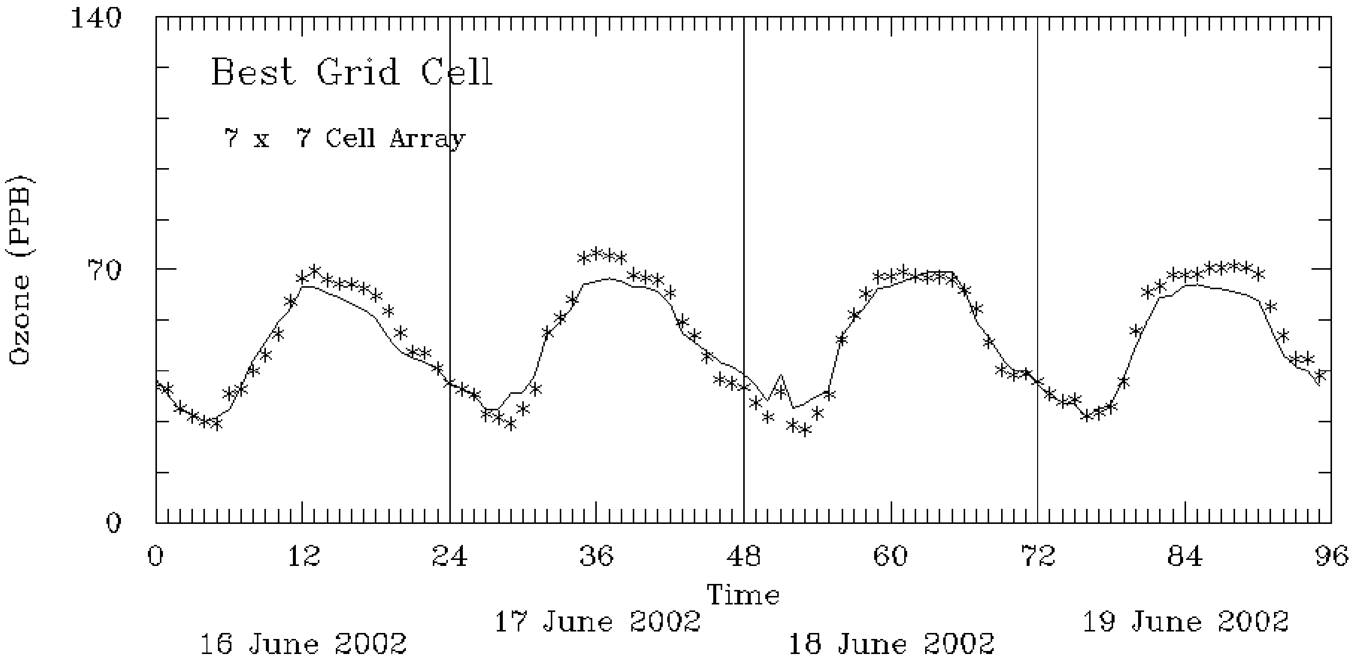


Figure 3-11a. Spatial Mean 1-hr Ozone Time Series Plot for Episode 2.

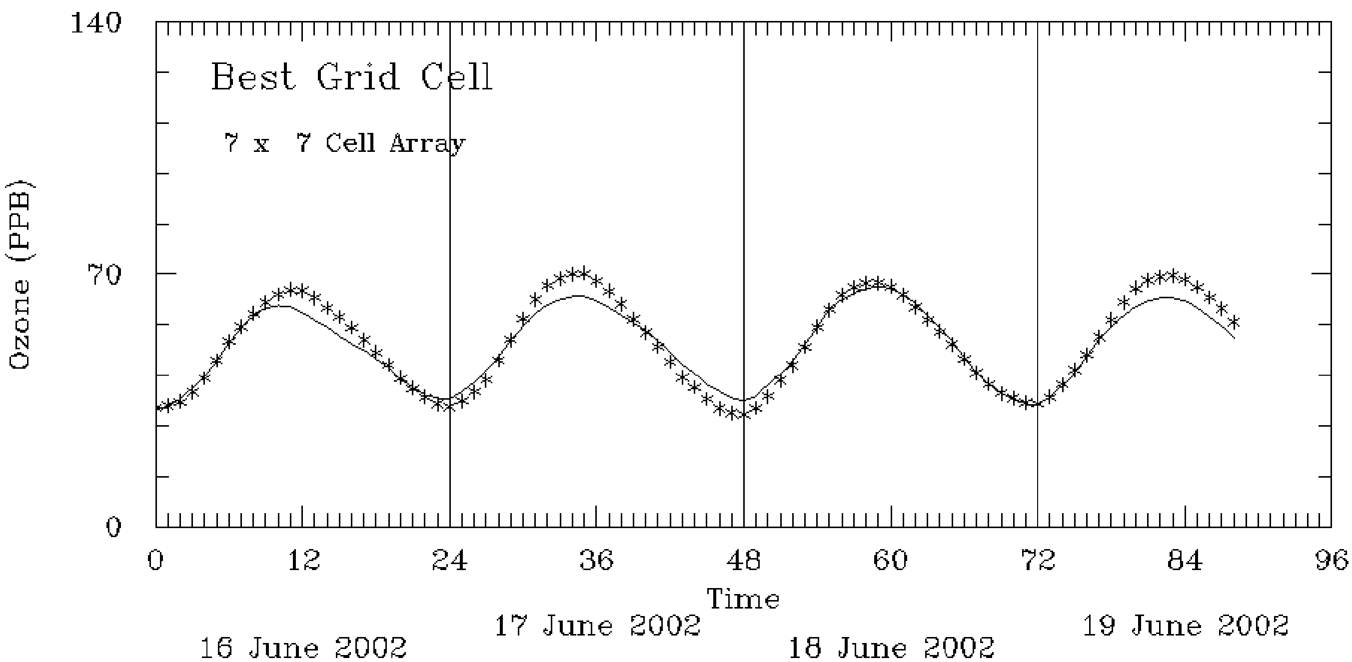


Figure 3-11b. Spatial Mean 8-hr Ozone Time Series Plot for Episode 2.

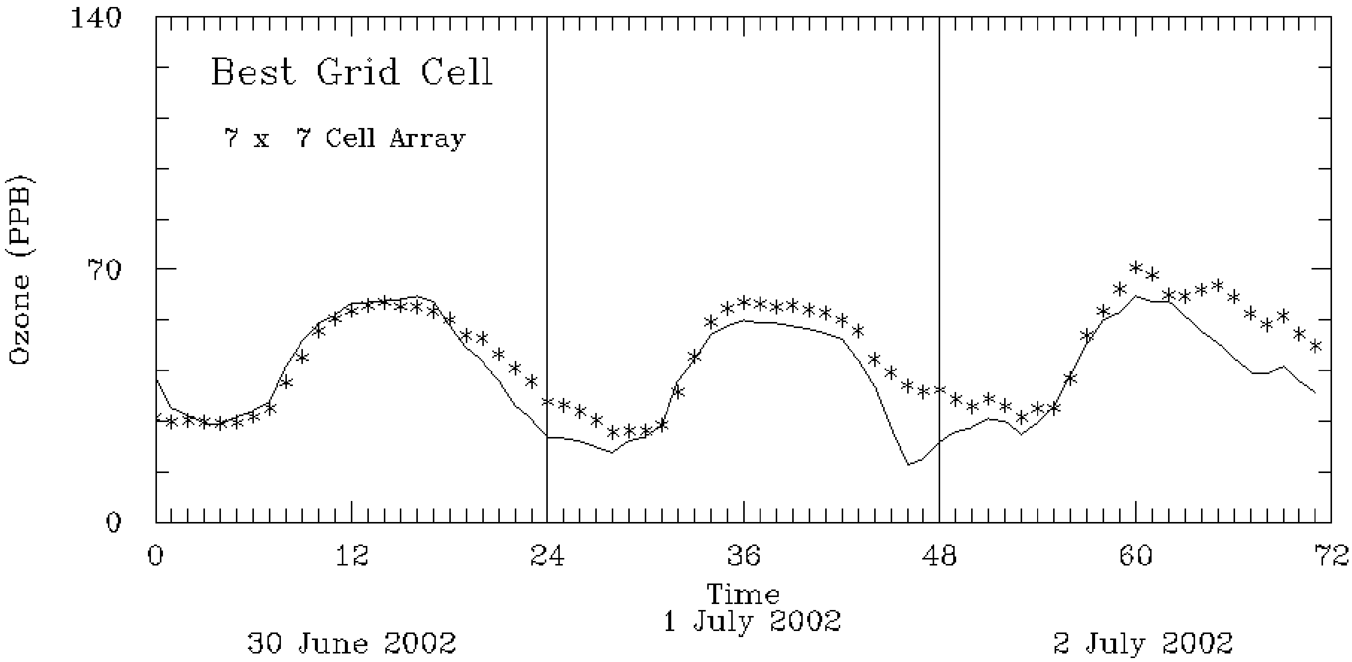


Figure 3-12a. Spatial Mean 1-hr Ozone Time Series Plot for Episode 3.

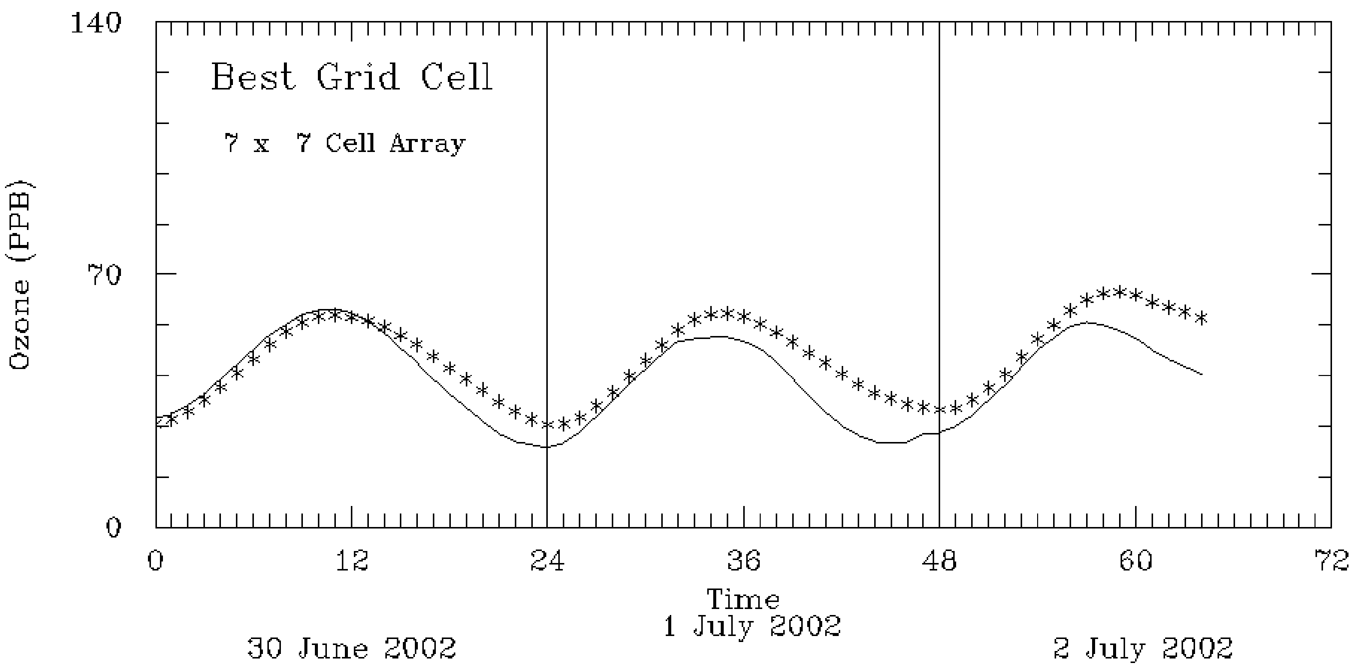


Figure 3-12b. Spatial Mean 8-hr Ozone Time Series Plot for Episode 3.

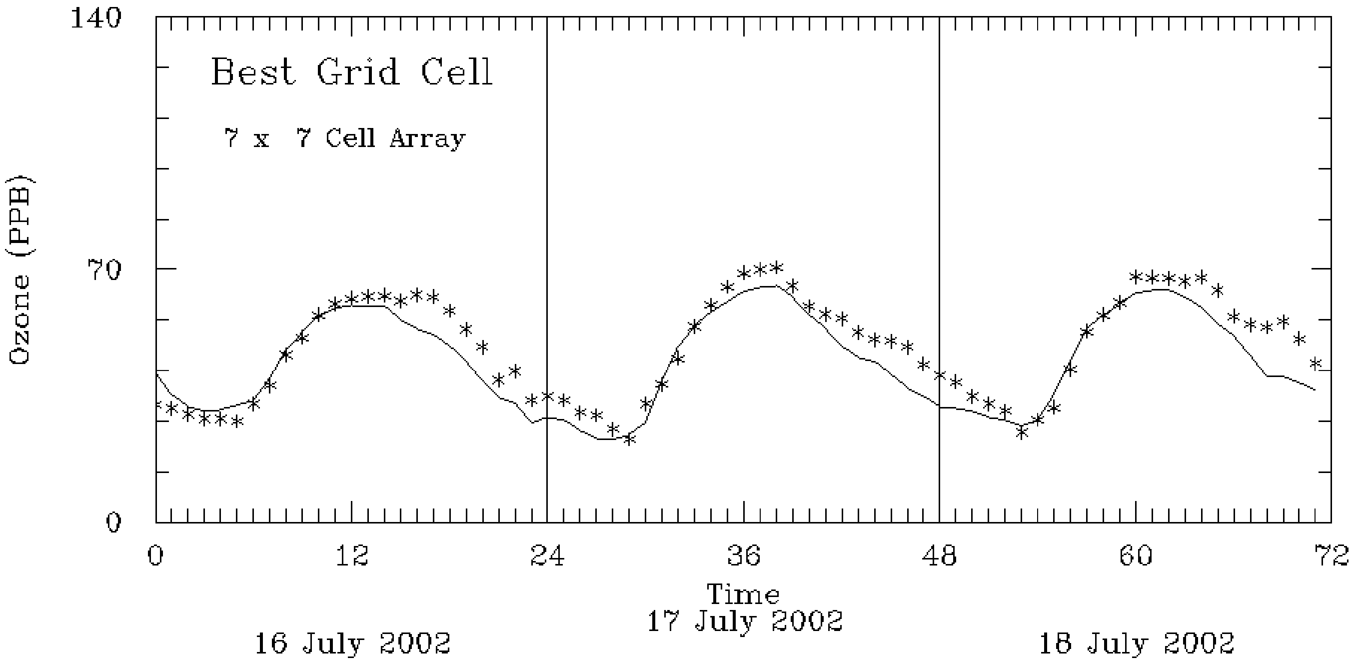


Figure 3-13a. Spatial Mean 1-hr Ozone Time Series Plot for Episode 4.

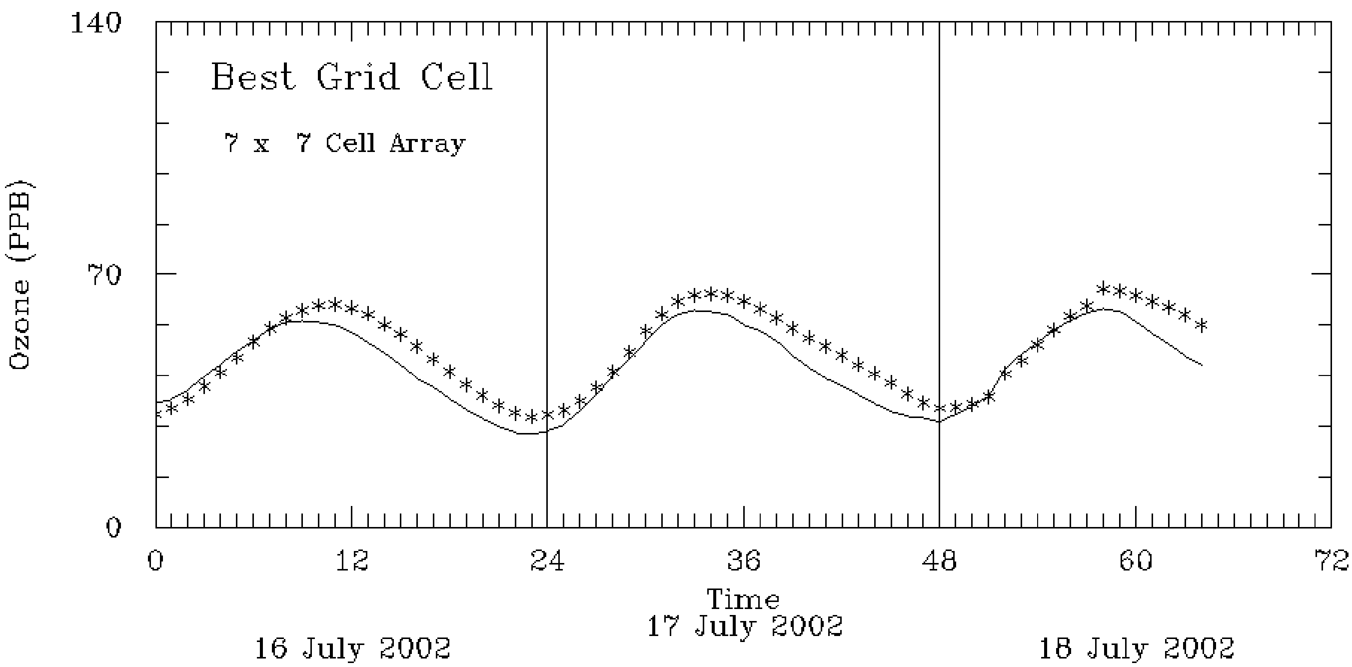


Figure 3-13b. Spatial Mean 8-hr Ozone Time Series Plot for Episode 4.

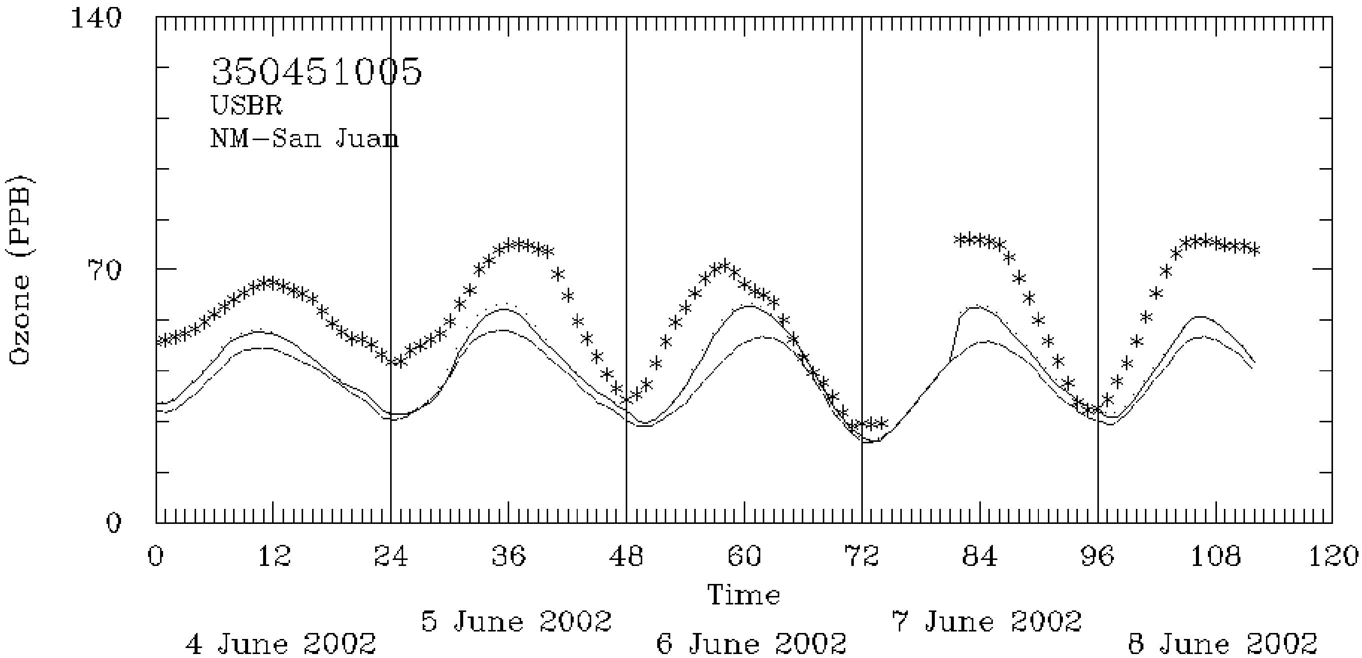


Figure 3-14a. Spatial Mean 8-hr Ozone Time Series Plot for Episode 1: Substation.

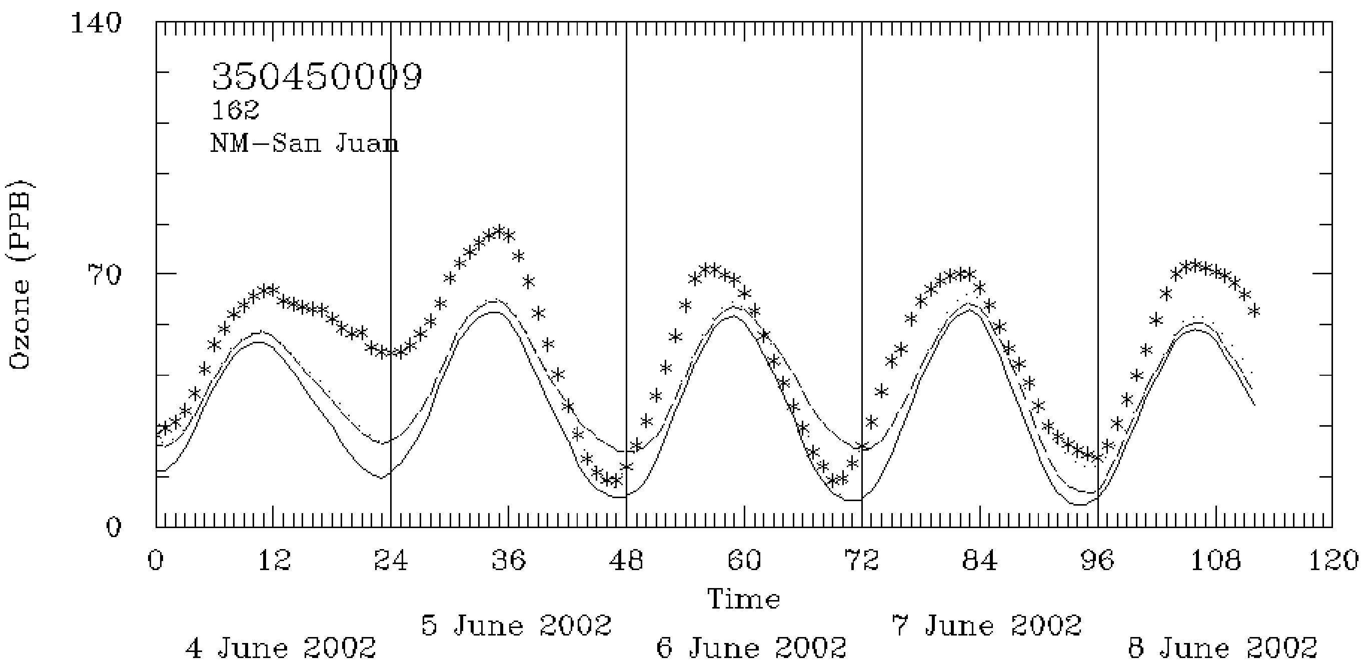


Figure 3-14b. Spatial Mean 8-hr Ozone Time Series Plot for Episode 1: Bloomfield.

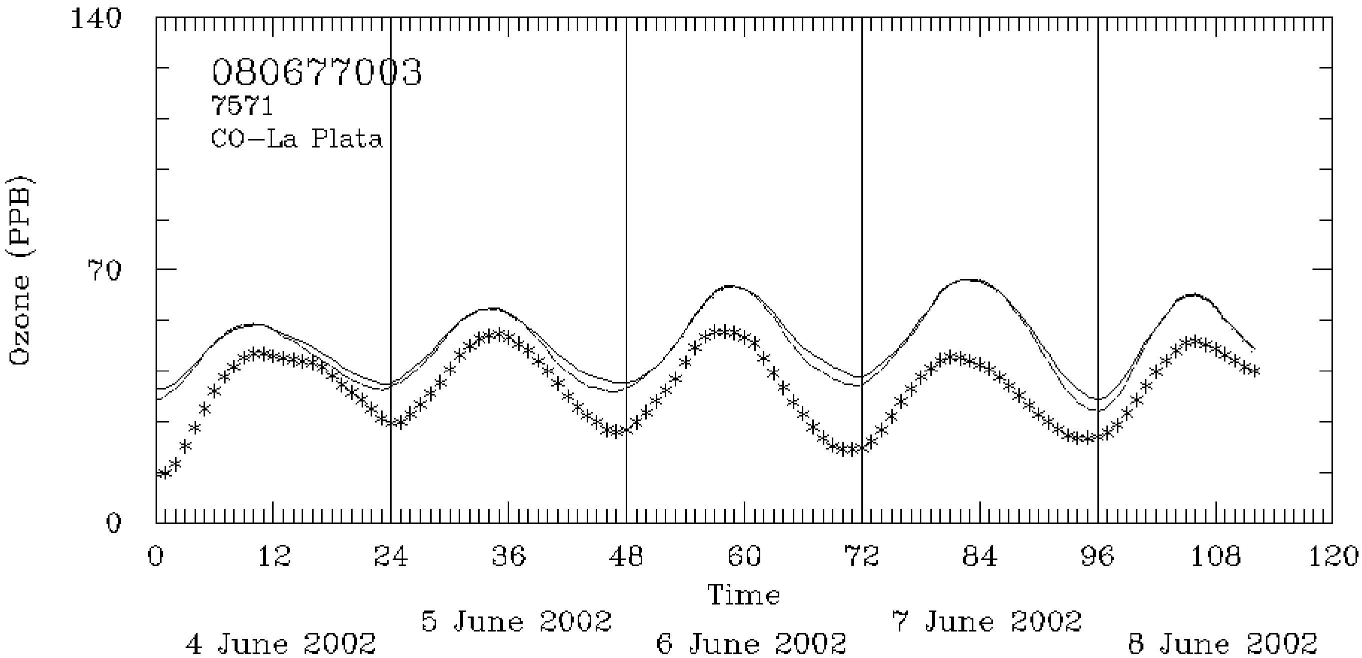


Figure 3-14c. Spatial Mean 8-hr Ozone Time Series Plot for Episode 1: Bondad.

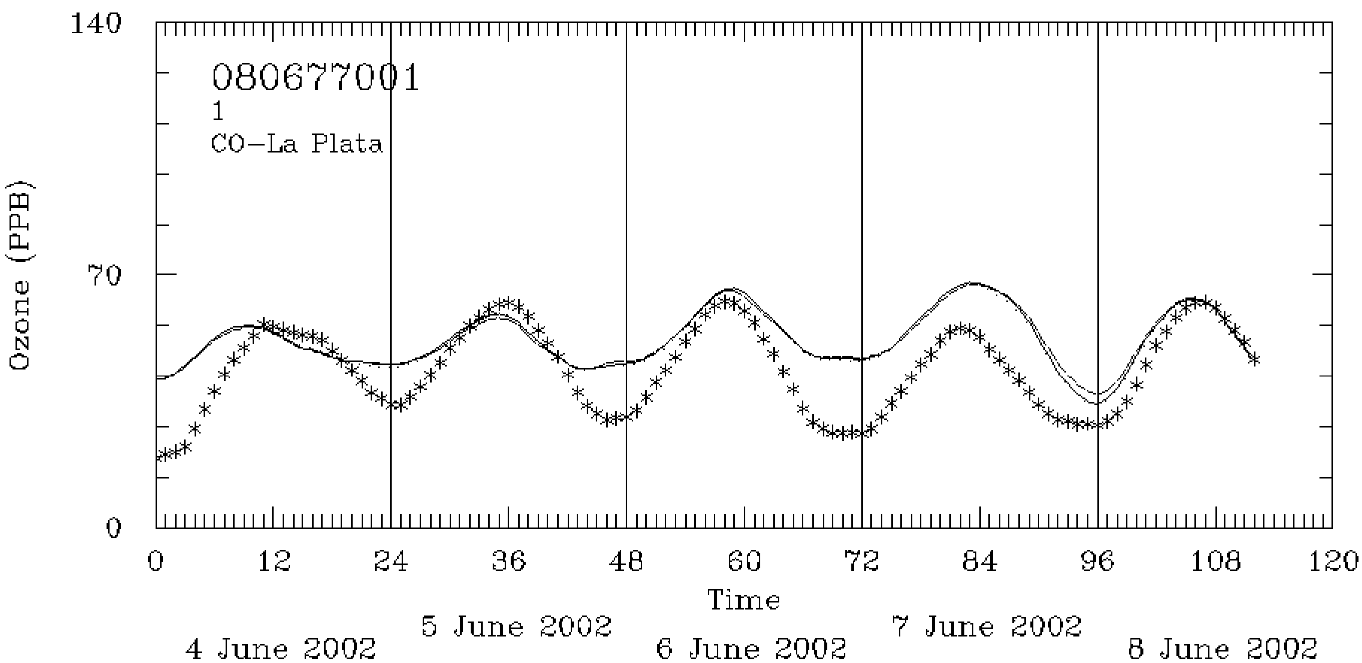


Figure 3-14d. Spatial Mean 8-hr Ozone Time Series Plot for Episode 1: Ignacio

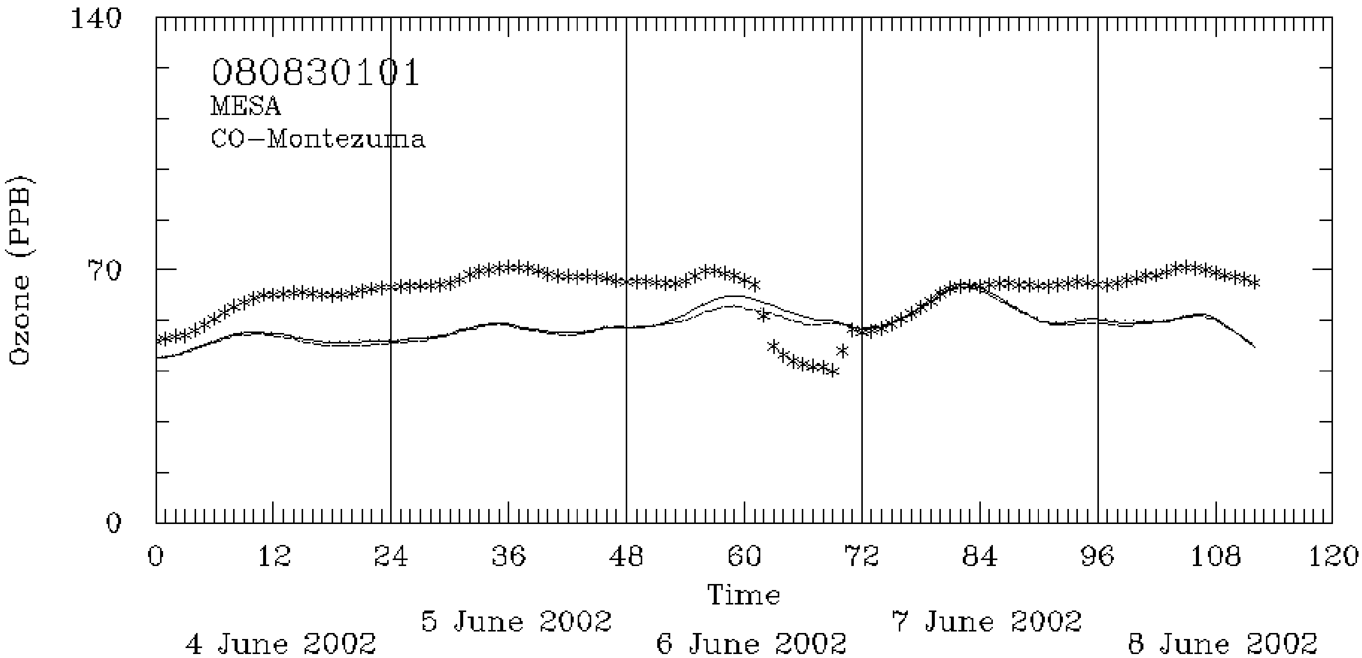


Figure 3-14e. Spatial Mean 8-hr Ozone Time Series Plot for Episode 1: Mesa Verde.

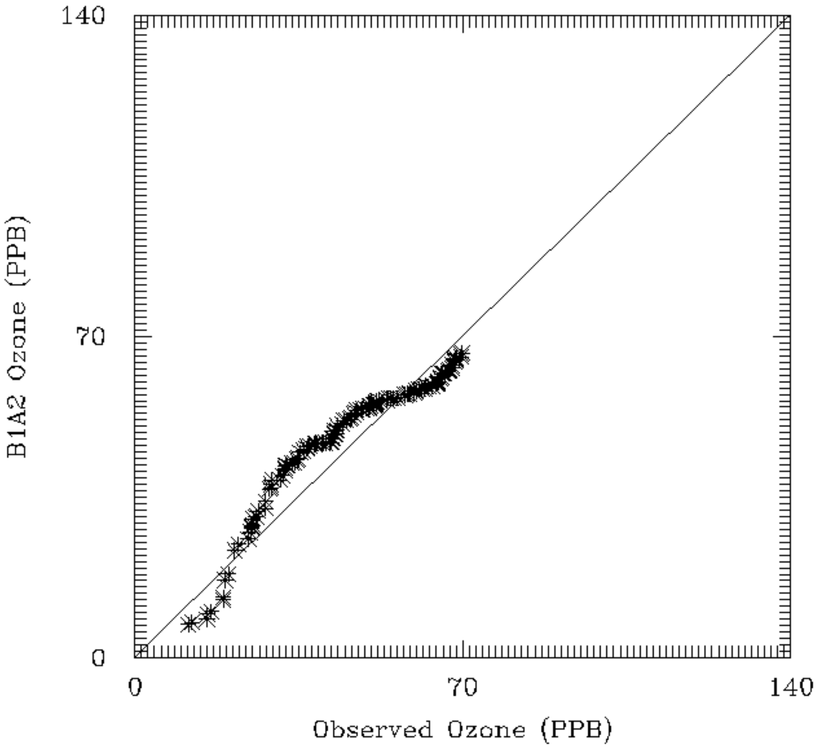


Figure 3-15a. Q-Q Plot of 8-hr Ozone Concentrations for Episode 1: 6 June 2002.

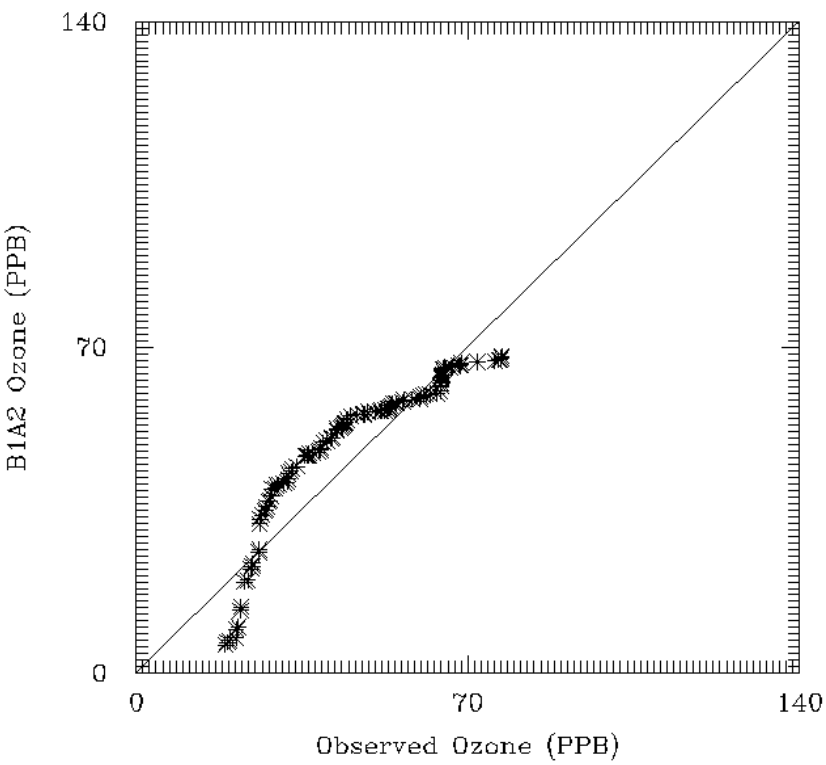


Figure 3-15b. Q-Q Plot of 8-hr Ozone Concentrations for Episode 1: 7 June 2002.

4.0 FUTURE YEAR BASELINE OZONE PROJECTIONS

This chapter describes the future-year (2007) Baseline modeling carried out as part of the San Juan-Four Corners 8-hour ozone Early Action Compact Study (San Juan EAC Study). The procedures used in the San Juan EAC photochemical modeling are described in detail in the modeling protocol (Tesche et al., 2003a).

4.1 2007 Emissions Inventory Development

The recent Task 4.2 Report by Mansell (2004) describes the 2007 base case emission inventory preparation for the four modeling episodes for the San Juan County, New Mexico EAC. Emission inventories were processed using version 2x of the Emissions Processing System (EPS2x) for area, off-road, on-road mobile and point sources. The purpose of the year 2007 emissions processing was to format the emission inventory for CAMx photochemical modeling. Data sources and processing steps used in developing the future year 2007 modeling inventory are documented in the Task 4.2 Report and so they are only briefly summarized here. We also include comparisons between the 2002 base year and 2007 future year emissions estimates to provide some perspective on the modeled changes in 8-hr ozone air quality over this five-year period.

4.1.1 Emissions Projection Methodology

For year 2007 modeling, CAMx requires two types of emission input files:

- Surface emissions from area, mobile, off-road, low-level point and biogenic sources spatially resolved (i.e., gridded) to the CAMx nested grid system. This means that separate surface emissions files will be prepared for the 36 km, 12 km and 4 km grids. The surface emissions are injected into the lowest layer of the model.

- Elevated emissions from major point sources that are injected into CAMx at the coordinates of each source. The plume rise of each source's emissions is calculated by CAMx from stack parameters so that the emissions are injected into the appropriate vertical layer.

Emissions for different major source groups (e.g., on-road mobile, off-road mobile, area, point and biogenic) were processed separately and merged together to produce "model-ready" emissions that represent day-specific, spatially gridded, chemically speciated and temporally (hourly) allocated. As discussed by Mansell (2004), the biogenic inventories were generated with GloBEIS version 3.1, which includes various enhancements to estimate the effects of drought conditions on biogenic emissions.

Several aspects of the future year 2007 inventory processing may be of particular interest. For example, the speciation of oil and gas sources in Northwest New Mexico was based on basin-specific data provided by New Mexico Oil and Gas Association (NMOGA, as discussed in Mansell and Dinh, (2003). Total unspeciated NOx emissions are allocated to NO and NO_2 components. Area and off-road mobile sources were estimated at the county level and allocated to the grid cells within each county based on spatial surrogates (e.g., population and economic activity). For the 2007 base case inventory, county-level emissions data, included growth and control assumptions, developed based on estimates available from EPA and EGAS. However, emissions estimates for the proposed Mustang Power Plant in New Mexico were provided by the NMED. Future year emission estimates for oil and gas production in the San Juan Basin were provided by NMOGA. For the state of Colorado, the Colorado Department of Public Health and Environment (CDPHE) provided the year 2007 emission inventory data as part of our companion Denver EAC study. For the remaining states within the modeling domain, several county-level emission inventories were used to develop the CAMx modeling inventories. A draft emission inventory for Mexico based on data used in the BRAVO study was incorporated into the inventory, primarily as a placeholder, until such time as a more accurate inventory for Mexico becomes available.

4.1.2 Point Source Projections

Point source data were obtained from different sources, processed separately and merged prior to running EPS2x for the 2007 baseline modeling. The separate point source data includes: Colorado point sources; Other State point sources; and Mexico point sources. As noted, NMED provided emission estimates for the Mustang power plant in San Juan County. The point source data were processed for a typical peak ozone (PO) season weekday and weekend day. The 2007 Colorado point source data were provided in EPS2x AFS input format. For all states other than Colorado, the U.S. EPA 2007 national inventories developed to assist future modeling of the Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel (i.e., the 2007 HDD inventory) were obtained from EPA.

4.1.3 On-Road Mobile Sources

On-road mobile source emissions were processed separately for the State of Colorado compared with the other states (including New Mexico) in the modeling domain and Mexico. For Colorado, high-resolution link-based emissions data was provided for the Denver metropolitan area because a detailed transportation model has been developed for this region over several years. No comparable transportation model has been developed for any city in New Mexico; accordingly EPA-derived vehicle miles traveled (VMT estimates were employed. HPMS-based VMT data provided by the CDPHE were used for the remaining counties in Colorado. On-road mobile emissions for Mexico were based on the draft inventory developed for the BRAVO study. California on-road mobile emissions were developed using the EMFAC2002 model. All other on-road mobile emission estimates including those for New Mexico were developed using the MOBILE6.2 model using EPA default inputs for a typical ozone season summer day. The resulting county-level 2007 emissions estimates were treated as area source and processed with EPS2x. A road type distribution (urban primary, rural primary, urban secondary, rural secondary) was used to spatially allocate the on-road sources grid cells in each of the modeling domains.

4.1.4 Off-Road Mobile Sources

Off-road mobile source emissions were developed using the NONROAD2002 model. The 2007 county-level off-road mobile source inventory was:(a) processed to extract the typical peak ozone season day data, (b) reformatted to AMS input file format and (c) processed with EPS2x. Since the NONROAD model does not provide estimates for locomotives, airports or commercial marine, emissions data for these source categories were obtained from the 2007 HDD inventory. These non-NONROAD source categories were processed using EPS2x in a manner similar to other area sources.

4.1.5 Oil and Gas Production Sources

Emissions data from oil and gas production wells within the modeling domain were obtained from NMOGA as well as the CDPHE. The CDPHE provided oil and gas emissions within the statewide inventory data files used for the Denver EAC project. Emissions data for oil and gas production in New Mexico was provided separately by NMOGA for numerous small un-permitted operations in the northeast corner of New Mexico. The development of oil and gas emissions in Colorado for air quality modeling is described in ENVIRON, 2003c.

In the San Juan Basin of New Mexico there are nearly 18,000 oil and gas wells in operation. Each of these emits only a relatively small amount of emissions and thus is not subject to permitting based on EPA guidelines. However, in aggregate, the large number of wells contributes a substantial amount of NOx and VOC to the overall inventory. NMOGA provided NOx and VOC emissions estimates for 2002 for the three New Mexico counties within the San Juan Basin; San Juan, Sandoval, and Rio Arriba (Gantner, 2003a). Flash, loading, working and standing, venting and fugitive VOC emission estimates were provided. NOx emissions for various engine types were provided on a basin wide basis. Emission estimates for 2007 were provided by NMOGA (Gantner, 2003b). NMOGA estimated a total increase in VOC emissions of 662.8 tons per year for loading, flash, working and standing, and fugitive emissions. No increase in venting emissions was projected for 2007. The increase in NOx emissions was estimated to be 5331 tons per year. NOx emissions for 2002 for the entire basin totaled 28,234 tons per year, resulting in an estimated 33,565 tpy of NOx for 2007 for the entire basin. The 2007 oil and gas emission estimates were not specified by county or process. Therefore, the total increase in VOC and NOx were distributed equally across all counties and applicable processes in the San Juan Basin.

The San Juan Basin includes several oil and gas formations that span all three counties. Speciation information by formation was provided with the emissions data. Although the EPS2 model includes default speciation profiles for oil and gas operations, it was desirable to develop specific profiles for these sources since the information required to do so was provided. Speciation profiles were developed separately for each of the four formations based on the information provided by NMOGA, as described in ENVIRON, 2003b. Because the emissions data was provided by county, and not separately for each formation, an average speciation profile was used for all formations.

Estimated VOC emissions for natural gas escaping to the atmosphere (e.g., fugitive emissions at gas wells) did not include ethane because EPA has excluded ethane from the definition of VOC. However, ethane does have some potential to form ozone and this is accounted for in the CB4 and SAPRC99 chemical mechanisms used for ozone modeling. Also, ethane is generally the second largest constituent of natural gas, after methane, and so ethane may be a significant component of the ozone formation potential of natural gas. Therefore, we calculated the emissions of ethane that were associated with the reported VOC emissions for natural gas so that this ethane could be accounted for in the ozone modeling. The ethane emissions were calculated using the ethane/VOC ratio determined by chemical analysis of natural gas produced in the northern New Mexico area.

Temporal allocation of the annual emissions for oil and gas operation was assumed constant for NOx emissions and VOC emissions except for working and standing emissions. For working and standing VOC emissions a specific monthly temporal profile was provided by NMOGA. Spatial allocation of emissions was based on the location of wells within each county for VOC emissions and on the location of wells across the entire basin for NOx emissions.

4.1.6 Biogenic Sources

Biogenic emissions were prepared using version 3.1 of the GloBEIS model (Yarwood et al., 1999 a,b). A discussion of the GloBEIS model, including options used in development of the inventory for the Denver/San Juan EAC modeling efforts was presented in ENVIRON, 2003a. GloBEIS was used to calculate day specific, gridded, speciated, hourly emissions of biogenic VOCs and NOx for each modeling grid (36 km, 12 km, 4 km). Biogenic emissions for 2007 are unchanged from the 2002 base year biogenic emissions.

4.1.7 Summary of Year 2007 Emissions Estimates

The merged 2007 gridded NO_x, VOC and CO emissions across the 4-km San Juan/Four Corners modeling domain for a typical ozone season weekday are displayed in Figure 4-1. Table 4-1 summarizes the changes in CO, VOC, and NOx emissions between the 2002 base case and 2007 future baseline emissions scenarios for San Juan County, NM. The projection of emissions from 2002 to 2007 in San Juan County results in decreases in total CO emissions by –19.0 tons/day (-12.2%). For VOCs, the total emissions decrease by –13.21 tons/day (-4.8%) while the reductions in NOx are –3.28 tons/day (-1.2%). However, there are some increases in emissions from individual source categories. For example, on-road CO and VOC emissions are projected to increase by 25.1% and 18.1% while NOx emissions are estimated to be reduced by –5.6%. Of course, biogenic emissions are assumed to remain the same as the year 2002 base case.

4.2 2007 Base Case Results

This section presents the highlights of the year 2007 future baseline CAMx simulations of the four San Juan modeling episodes. In accordance with the San Juan modeling protocol and using the projected emissions inventories summarized above and described in detail by Mansell (2004), we exercised the model for each episode assuming no changes to: (a) the base year 2002 meteorological conditions, (b) the initial and boundary conditions, and (c) the biogenic emissions. Full details of the year 2007 modeling results have been archived on CD, stratified as follows:

- By pollutant species (e.g., CO, NO, NO_2, NO_x and O_3);
- By averaging time (e.g., 1-hr and 8-hr);
- By grid domain (e.g., 36 km, 12km,and 4 km);
- By state; and
- By subregion: e.g., Four Corners Region.

The 2007 future baseline results on the CD are formatted in a manner identical to the base case results for 2002. Additional information on the future year baseline results may also be found in the three PowerPoint presentation files that were presented to the San Juan EAC Technical Peer Review Committee and to the public workshop on 14 January 2004 in Farmington, NM, namely:

- “San Juan 8-hr Ozone EAC Study: Model Performance and Future Year Ozone Levels: Executive Summary”;

> "San Juan 8-hr Ozone EAC Study: Model Performance and Future Year Ozone Levels"; and

> "San Juan 8-hr Ozone EAC Study: Model Performance and Future Year Ozone Levels: Appendix A: CAMx Base Case 1-hr Model Performance Results".

In the following subsections, we present the highlights of the future year simulations.

4.2.1 Daily Maximum 8-hr Ozone Impacts Across the Four Corners Region

We developed hourly color contour maps (i.e., tile plots) of the predicted 1-hr and moving 8-hr ozone concentration fields for each future year episode day. Appendix A presents the daily maximum 8-hr ozone concentrations for the principal days of each episode. For example, Figure 4-2 shows the modeled daily maximum 8-hr ozone field on 5 June 2007 across the 4 km domain. The statistics at the top of each page present the maximum, minimum, average, and grid total 8-hr ozone concentrations (in ppb) for each simulation day. From this figure, the region-wide maximum predicted 8-hr ozone value on this day was 66.3 ppb in grid cell [123,18], corresponding to a 4 km grid cell northwest of Rio Rancho Estates in Bernalillo County (~ 15 miles north of Albuquerque) adjacent to Highway 550 leading north to San Ysidro. In the Four Corners area on this day, the maximum predicted 8-hr concentrations were lower, ranging from a low of 56.5 ppb at Mesa Verde to a high of 63.4 ppb at Bloomfield. (For convenience, the measured 8-hr ozone concentrations in 2002 at each monitoring station in the 4 km Four Corners Region domain are denoted by the solid black numeral.) Perusal of the daily plots in Appendix A reveals that only on 30 June 2007 did the maximum 8-hr ozone concentration over the full 4 km domain fall within the Four Corners region.

Because the differences between the 2002 and 2007 baseline ozone predictions are, in most cases, so small at the four monitors in the Four Corners region, we present in Appendix B the daily maximum 8-hr ozone *residual concentration* fields for the principal days of each episode. These residual concentration plots are constructed by subtracting the year 2007 results from the year 2007 baseline results. Thus, if ozone is predicted to be reduced in the year 2007, the concentration change would be negative. If ozone goes up in 2007, the change would be positive. Again using the 5 June 2007 day as an example, Figure 4-3 shows the modeled daily maximum 8-hr ozone residual concentration field across the 4 km domain. The statistics at the top of each page present the maximum, minimum, average, and grid total 8-hr ozone residual concentration (in ppb) for 5 June 2007. From this figure, the region-wide maximum predicted 8-hr ozone increase in 2007 is 9 ppb near Navajo Dam (i.e., grid cell [91,64]) approximately 10 miles northeast of Bloomfield. Clearly, from Figure 4-2, this increase of 9 ppb above year 2002 levels on this day still only elevates the 8-hr ozone concentrations in this location to 60-65 ppb (the middle shade of blue).

Examination of the daily 8-hr ozone residual plots in Appendix B shows that on most year 2007 modeling days there are local increases and decreases in 8-hr ozone concentrations in the Four Corners region relative to base case 2002 predictions. However, it is clear from the results in Appendix A that in no case do the predicted 2007 8-hr concentrations reach or exceed 75 ppb on any day anywhere within the Four Corners region. In other words, throughout the full set of modeling days, there is no instance where future year 8-hr ozone concentrations either at a monitor or in the general San Juan Basin rise above 75 ppb.

We next examine the predicted 8-hr ozone increases and decreases within the 7 x 7 grid array neighborhoods of each of the five regulatory monitors in the San Juan Basin.

4.2.2 Daily Maximum 8-hr Ozone Impacts At Regulatory Monitoring Stations

For all fifteen (15) future year modeling days in 2007, we extracted the maximum 8-hr ozone concentrations estimated by CAMx within neighborhoods of 7 x 7 4km grid cells surrounding the five regulatory monitors in the San Juan Basin. Presented in Tables 4-2a through 4-2c, these predictions are compared with the corresponding neighborhood maxima in the 2002 base case simulations and the actual measurements at the monitors. These results are depicted graphically in Figures 4-4 though 4-8. The maximum 8-hr ozone concentrations over all modeling days at the two New Mexico monitors are 72.1 ppb (Bloomfield) and 72.2 ppb (Substation). In Colorado, the maximum 8-hr ozone predictions across the full set of episode were 70.5 ppb (Ignacio), 69.1 ppb (Bondad), and 71.7 ppb (Mesa Verde). Except for Bloomfield, across all days the peak 8-hr concentrations tended to decrease relative to year 2002 levels.

The average peak daily 8-hr ozone levels are also presented in the tables. Typically the average peaks were 6.5 ppb to 10.4 ppb less than the maximum values overall days. As shown in Tables 4-2a through 4-2c, these changes ranged from –0.4 ppb at Subtation to –5.1 ppb at Bondad. The Bloomfield monitor was the only one where year 2007 peak 8-hr ozone levels tended on increase. However, this average increase (0.1 ppb) is quite small and certainly well within the uncertainty of the modeling system.

4.3 Assessment

Examination of the year 2007 8-hr ozone modeling results reveals a very consistent picture. Changes are predicted to occur in daily maximum 8-hr ozone concentrations from 2002 to 2007 but these changes are generally very small (i.e., a few ppb) and are typically negative. That is, on most days, predicted peak ozone levels in 2007 in the neighborhood of the regulatory monitors decrease by a few ppb from year 2002 baseline levels. On 15% of the days at the Colorado monitors where year 2007 ozone levels at the Colorado monitors increase above those predicted by CAMx for the 2002 base year. At the Substation and Bloomfield monitors, ozone increases occur on less than half the modeling days and these increases are limited to 0.1 ppb to 3.1 ppb (mean of 1.2 ppb.) The maximum 'neighborhood' 8-hr ozone concentrations for 2007 over all episodes are 72.1 ppb at Bloomfield, 72.2 ppb at Substation, 70.5 ppb at Ignacio, 69.1 ppb at Bondad , and 71.7 ppb at Mesa Verde. Moreover, beyond the neighborhoods of these regulatory monitors but within the general Four Corners/San Juan Basin region the future year 8-hr ozone concentrations are below 75 ppb on all fifteen modeling days.

Table 4-1. Change in San Juan County Emissions from 2002 to 2007 (adapted from Mansell, 2004).

Category	CO	VOC	NOx
2002 Baseline Emissions (tons/day)			
Area	5.10	14.54	2.18
Off-Road	30.13	2.07	3.34
On-Road	47.47	4.75	8.61
Point	37.77	14.67	247.75
Biogenic	35.73	241.54	20.57
total	156.20	277.57	282.45
2007 Baseline Emissions (tons/day)			
Area	2.25	12.40	2.31
Off-Road	26.09	1.82	2.16
On-Road	59.38	5.61	8.13
Point	13.66	2.99	246.00
Biogenic	35.73	241.54	20.57
total	137.11	264.36	279.17
Change from 2002 to 2007 (tons/day)			
Area	-2.85	-2.14	0.13
Off-Road	-4.04	-0.25	-1.18
On-Road	11.91	0.86	-0.48
Point	-24.11	-11.68	-1.75
Biogenic	0.00	0.00	0.00
total	-19.09	-13.21	-3.28
Change from 2002 to 2007 (%)			
Area	-55.9%	-14.7%	6.0%
Off-Road	-13.4%	-12.1%	-35.3%
On-Road	25.1%	18.1%	-5.6%
Point	-63.8%	-79.6%	-0.7%
Biogenic	0.0%	0.0%	0.0%
total	-12.2%	-4.8%	-1.2%

Table 4-2a. Comparison of Base Year and Future Year Daily Maximum 8-hr Ozone (ppb).									
		Bloomfield				Substation			
Date	Day	2002 Obs.	2002 Base	2007 Base	Change	2002 Obs.	2002 Base	2007 Base	Change
04-Jun	155	64.3	56.6	56.8	-0.2	65.0	53.7	54.0	-0.2
05-Jun	156	80.6	63.4	63.7	-0.3	75.8	61.5	64.2	-2.7
06-Jun	157	69.9	64.0	63.8	0.1	69.6	62.8	63.1	-0.3
07-Jun	158	68.6	66.3	66.9	-0.6	77.1	62.4	62.9	-0.5
08-Jun	159	71.0	60.4	60.3	0.1	76.8	58.3	58.2	0.1
16-Jun	167	71.5	64.8	64.7	0.1	73.8	63.6	64.0	-0.4
17-Jun	168	74.3	66.7	66.8	-0.1	80.4	64.7	65.0	-0.3
18-Jun	169	73.5	68.2	68.2	0.0	75.1	67.3	67.1	0.1
19-Jun	170	76.8	68.3	66.7	1.6	74.6	65.0	64.2	0.8
30-Jun	181	63.0	64.8	72.1	-7.3	64.3	64.3	72.2	-7.9
01-Jul	182	61.4	55.6	55.8	-0.2	64.4	55.3	54.3	1.0
02-Jul	183	78.8	62.8	62.9	-0.1	72.3	58.9	58.9	0.0
16-Jul	197	68.1	60.1	57.8	2.3	70.3	60.8	59.0	1.8
17-Jul	198	74.5	65.2	62.7	2.5	74.3	64.4	63.2	1.2
18-Jul	199	79.2	63.3	60.2	3.1	67.1	57.8	56.4	1.3
Average		71.7	63.4	63.3	0.1	72.0	61.4	61.8	-0.4
Max.		80.6	68.3	72.1	3.1	80.4	67.3	72.2	1.8

Table 4-2b. Comparison of Base Year and Future Year Daily Maximum 8-hr Ozone (ppb).

		Ignacio				Bondad			
Date	Day	2002 Obs.	2002 Base	2007 Base	Change	2002 Obs.	2002 Base	2007 Base	Change
04-Jun	155	54.9	54.8	58.1	-3.2	45.5	51.9	56.9	-5.0
05-Jun	156	60.9	60.8	60.9	0.0	50.8	54.8	61.0	-6.1
06-Jun	157	61.3	64.4	66.4	-2.0	51.5	61.4	66.4	-4.9
07-Jun	158	53.9	65.9	68.6	-2.8	44.5	63.1	68.0	-4.9
08-Jun	159	61.0	62.2	65.0	-2.8	48.9	60.5	64.0	-3.5
16-Jun	167	56.9	58.9	62.2	-3.3	53.5	57.8	61.7	-4.0
17-Jun	168	61.8	63.1	66.2	-3.2	60.4	61.4	66.2	-4.9
18-Jun	169	60.5	65.4	68.4	-3.1	57.1	63.5	68.4	-4.9
19-Jun	170	60.5	62.3	70.5	-8.2	58.3	60.2	69.1	-8.8
30-Jun	181	54.8	58.4	63.1	-4.7	45.6	58.2	64.6	-6.4
01-Jul	182	56.8	53.5	52.7	0.8	47.8	49.0	53.3	-4.3
02-Jul	183	56.1	54.9	53.9	1.0	49.8	51.0	56.9	-6.0
16-Jul	197	50.8	51.7	56.7	-5.0	46.1	53.7	59.1	-5.4
17-Jul	198	54.0	54.2	59.6	-5.5	49.3	56.2	60.9	-4.8
18-Jul	199	60.4	60.4	60.8	-0.4	53.8	59.7	62.0	-2.3
Average		57.6	59.4	62.2	-2.8	50.8	57.5	62.6	-5.1
Max.		61.8	65.9	70.5	1.0	60.4	63.5	69.1	-2.3

Table 4-2c. Comparison of Base Year and Future Year Daily Maximum 8-hr Ozone (ppb).

		Mesa Verde			
Date	Day	2002 Obs.	2002 Base	2007 Base	Change
04-Jun	155	63.8	53.6	53.6	0.0
05-Jun	156	69.3	56.5	56.5	0.0
06-Jun	157	68.4	64.9	65.7	-0.8
07-Jun	158	65.3	64.3	66.9	-2.6
08-Jun	159	69.3	59.3	58.8	0.4
16-Jun	167	68.6	62.4	63.2	-0.8
17-Jun	168	70.9	65.7	66.1	-0.3
18-Jun	169	70.9	70.8	71.7	-0.9
19-Jun	170	77.5	62.6	62.5	0.1
30-Jun	181	61.5	61.3	63.8	-2.5
01-Jul	182	60.5	52.7	52.6	0.1
02-Jul	183	65.1	56.8	56.8	0.0
16-Jul	197	67.0	60.2	57.8	2.4
17-Jul	198	66.0	62.0	61.7	0.3
18-Jul	199	63.9	63.4	63.7	-0.3
Average		67.2	61.1	61.4	-0.3
Max.		77.5	70.8	71.7	2.4

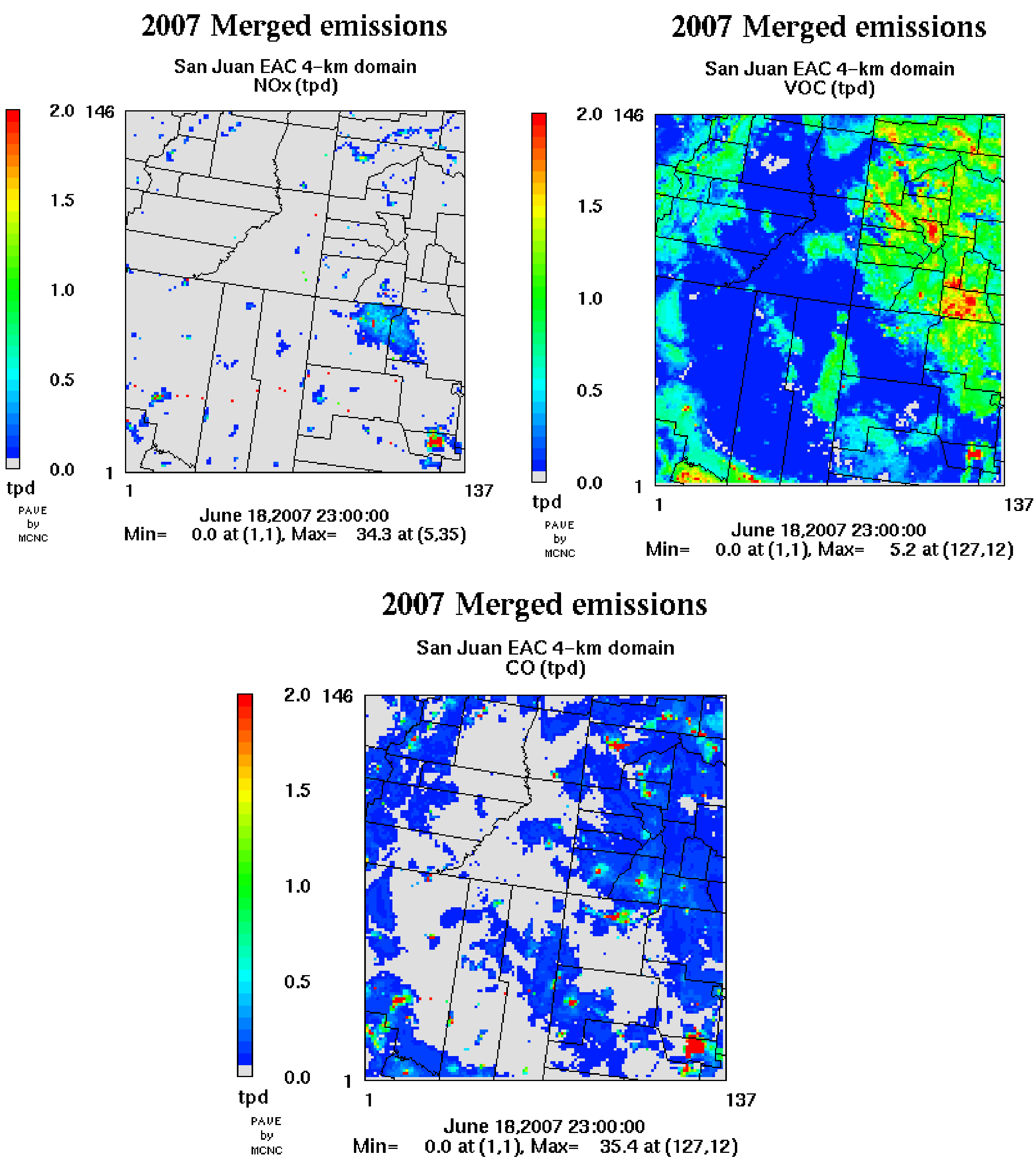


Figure 4-1. Total Year 2007 Baseline Emissions Used in the San Juan EAC Ozone Modeling (Source: Mansell, 2004).

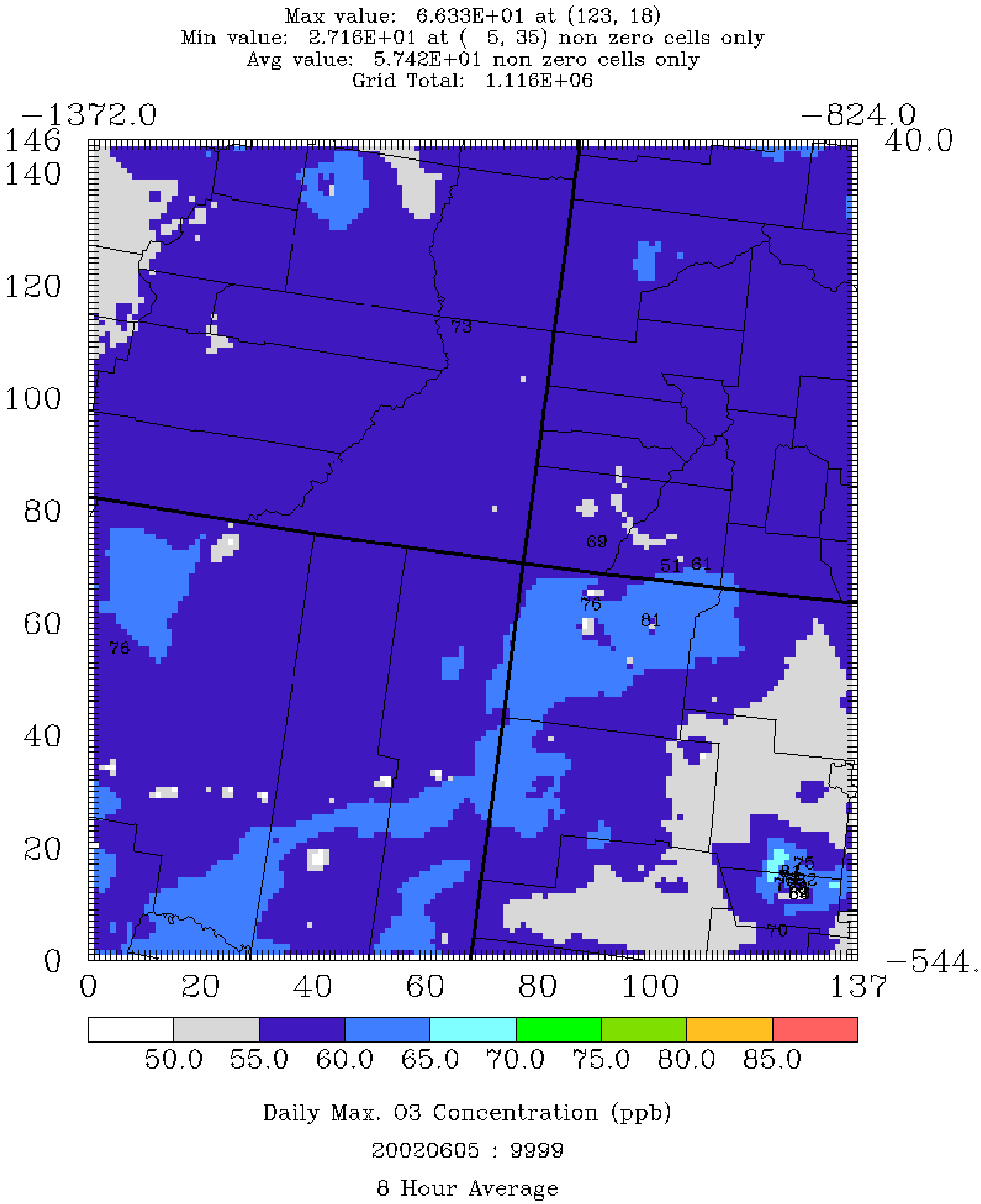


Figure 4-2. Daily Maximum 8-hr Ozone Concentrations on 5 June 2007.

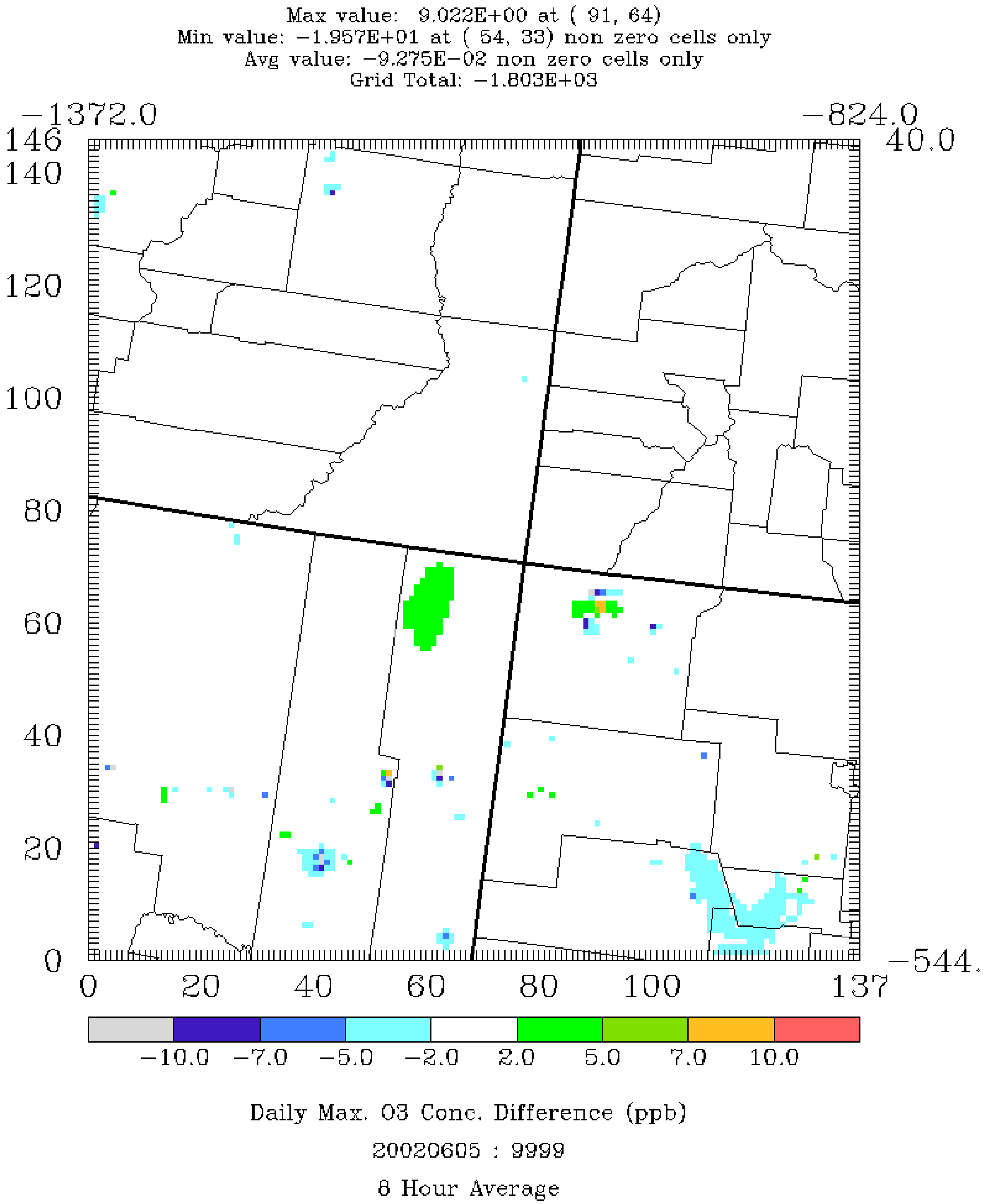


Figure 4-3. Daily Maximum 8-hr Ozone Residuals (2007 minus 2002) on 5 June 2007.

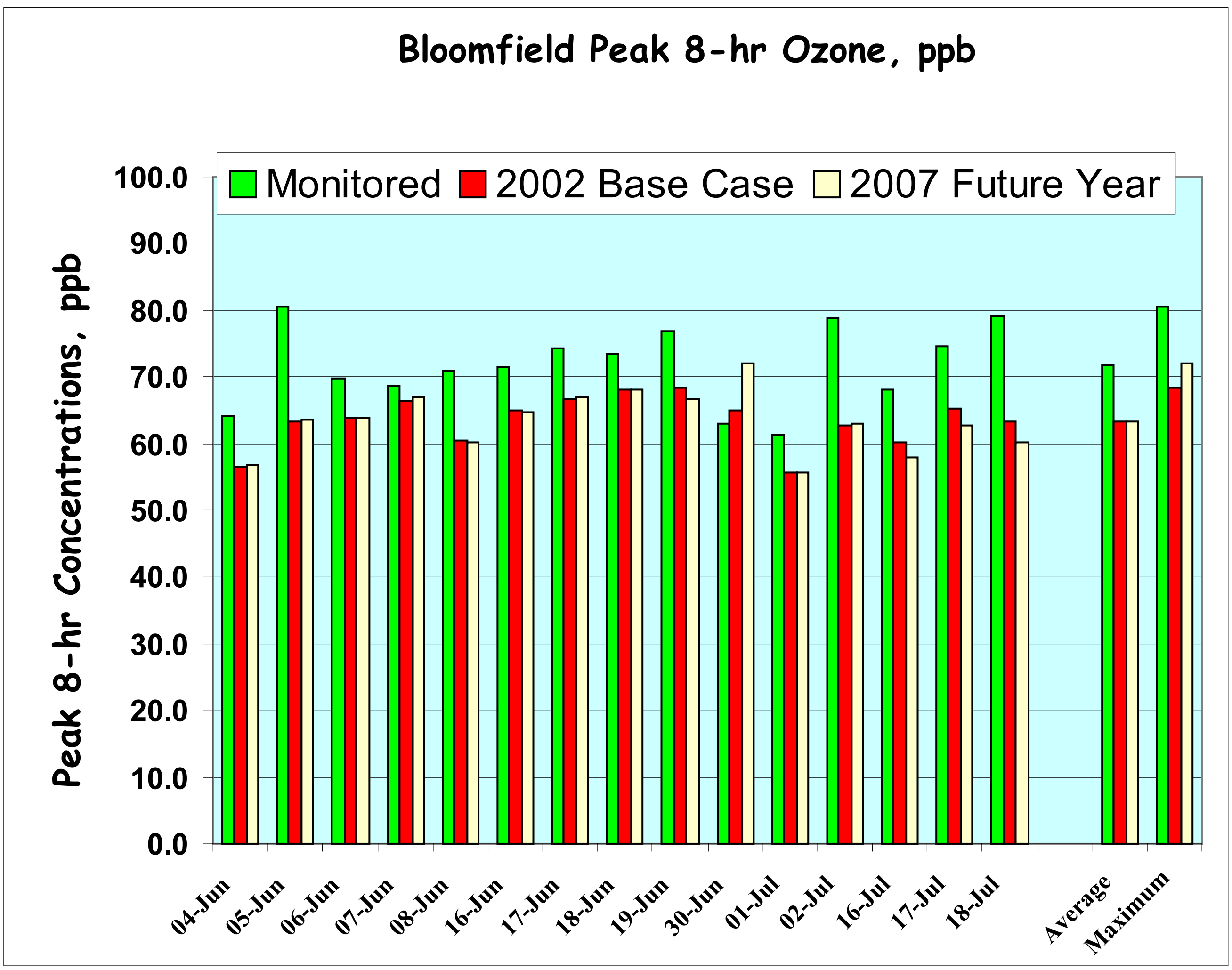


Figure 4-4. Daily Maximum 8-hr Ozone Predictions at Bloomfield.

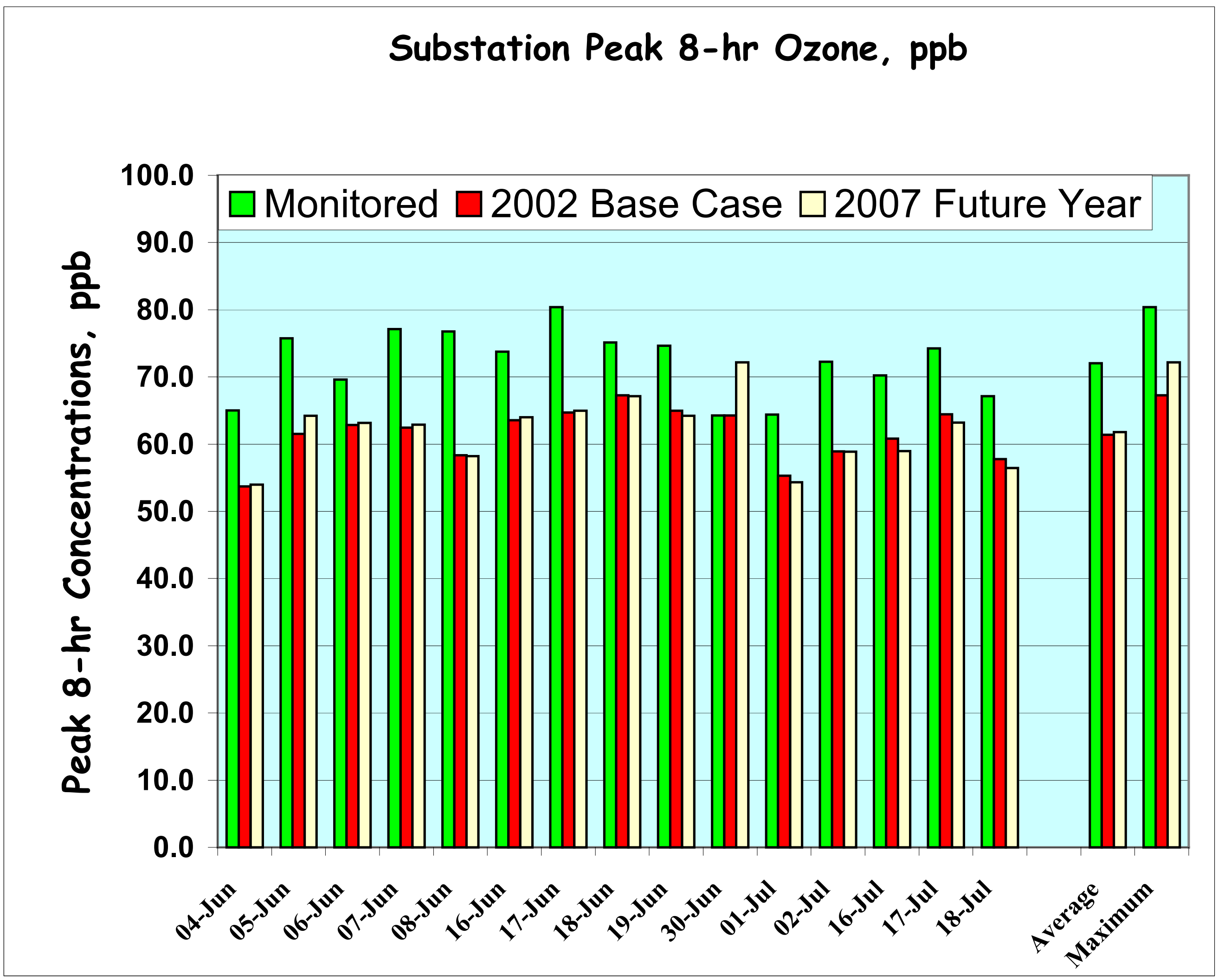


Figure 4-5. Daily Maximum 8-hr Ozone Predictions at Substation.

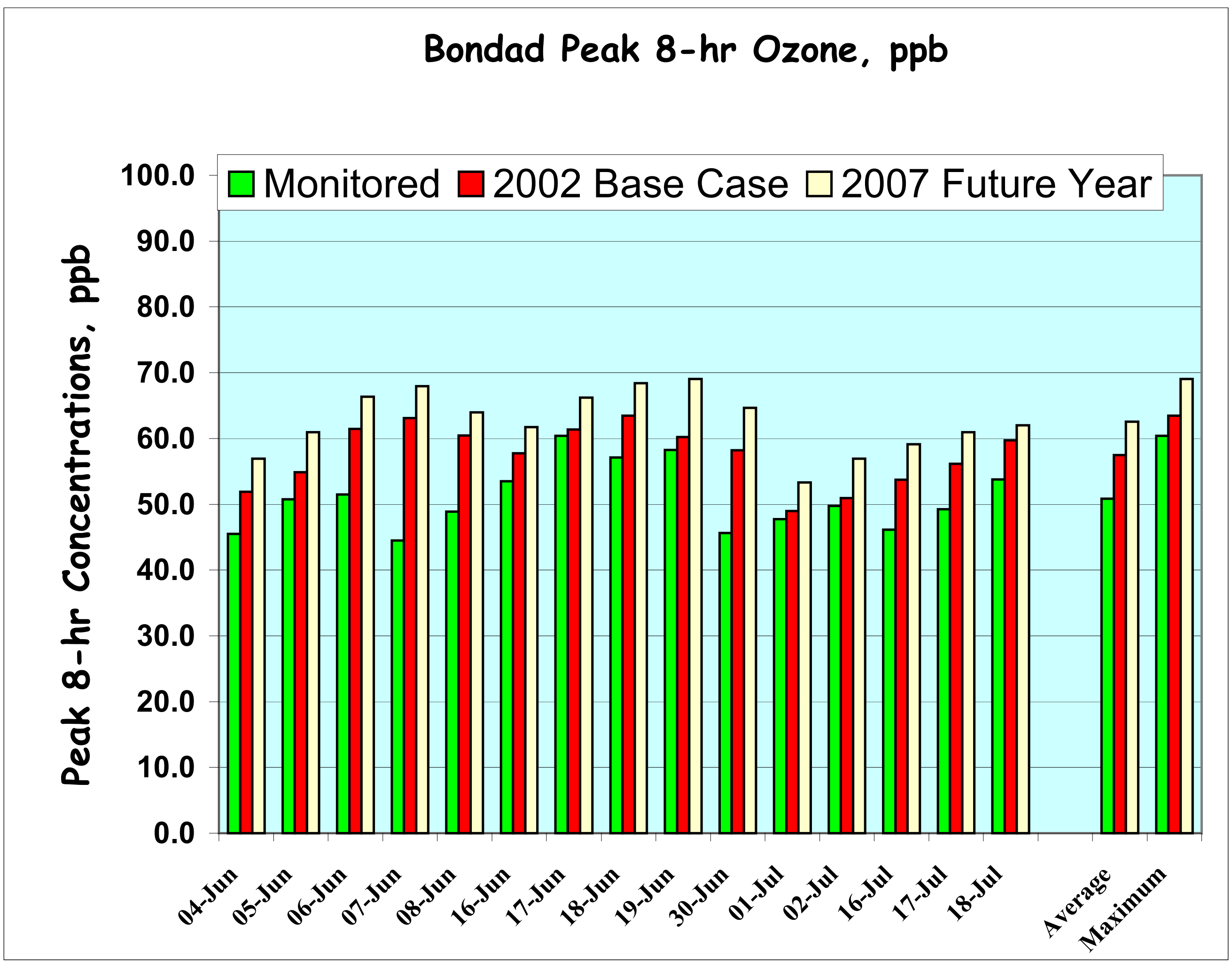


Figure 4-6. Daily Maximum 8-hr Ozone Predictions at Bondad.

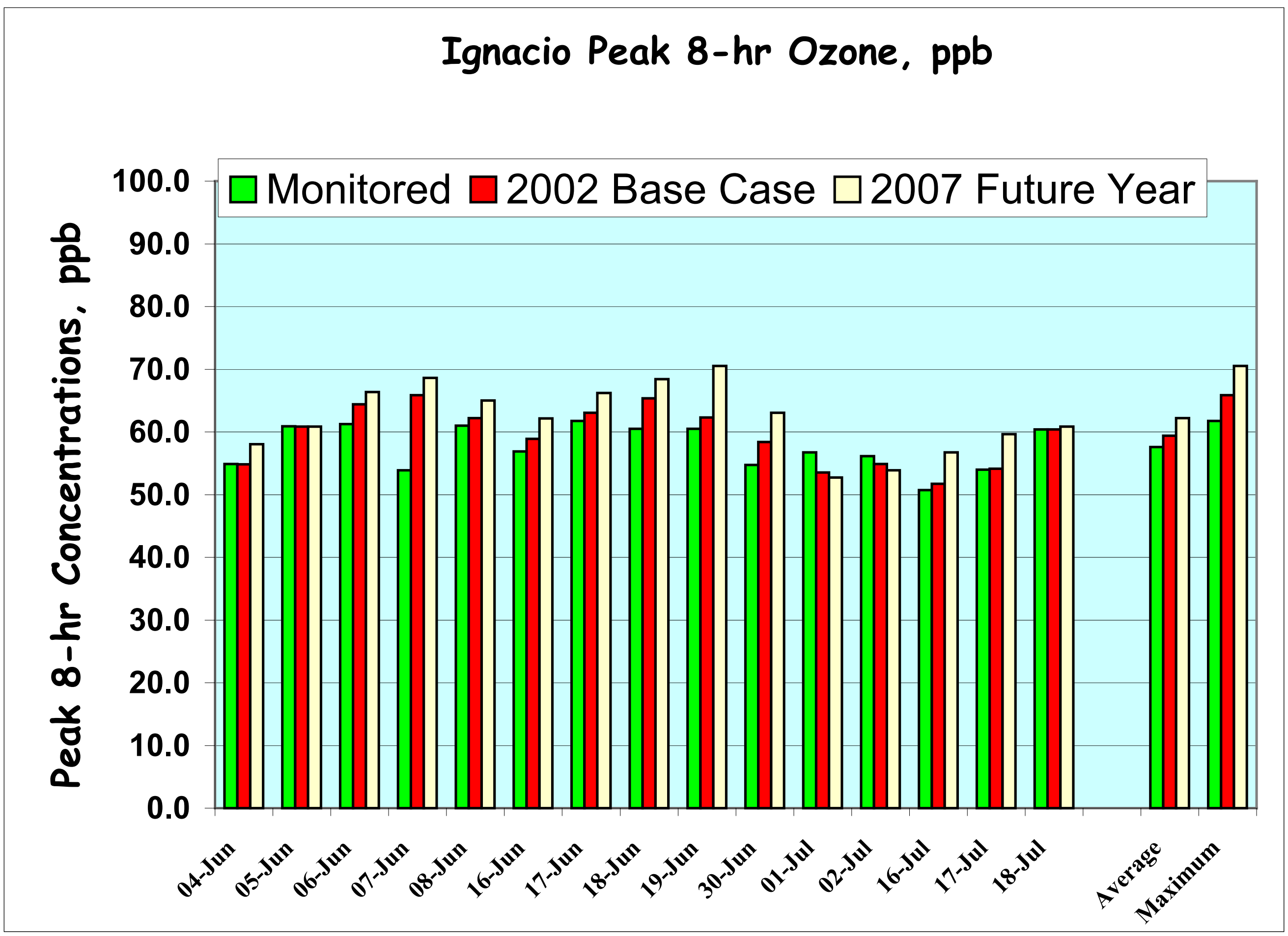


Figure 4-7. Daily Maximum 8-hr Ozone Predictions at Ignacio.

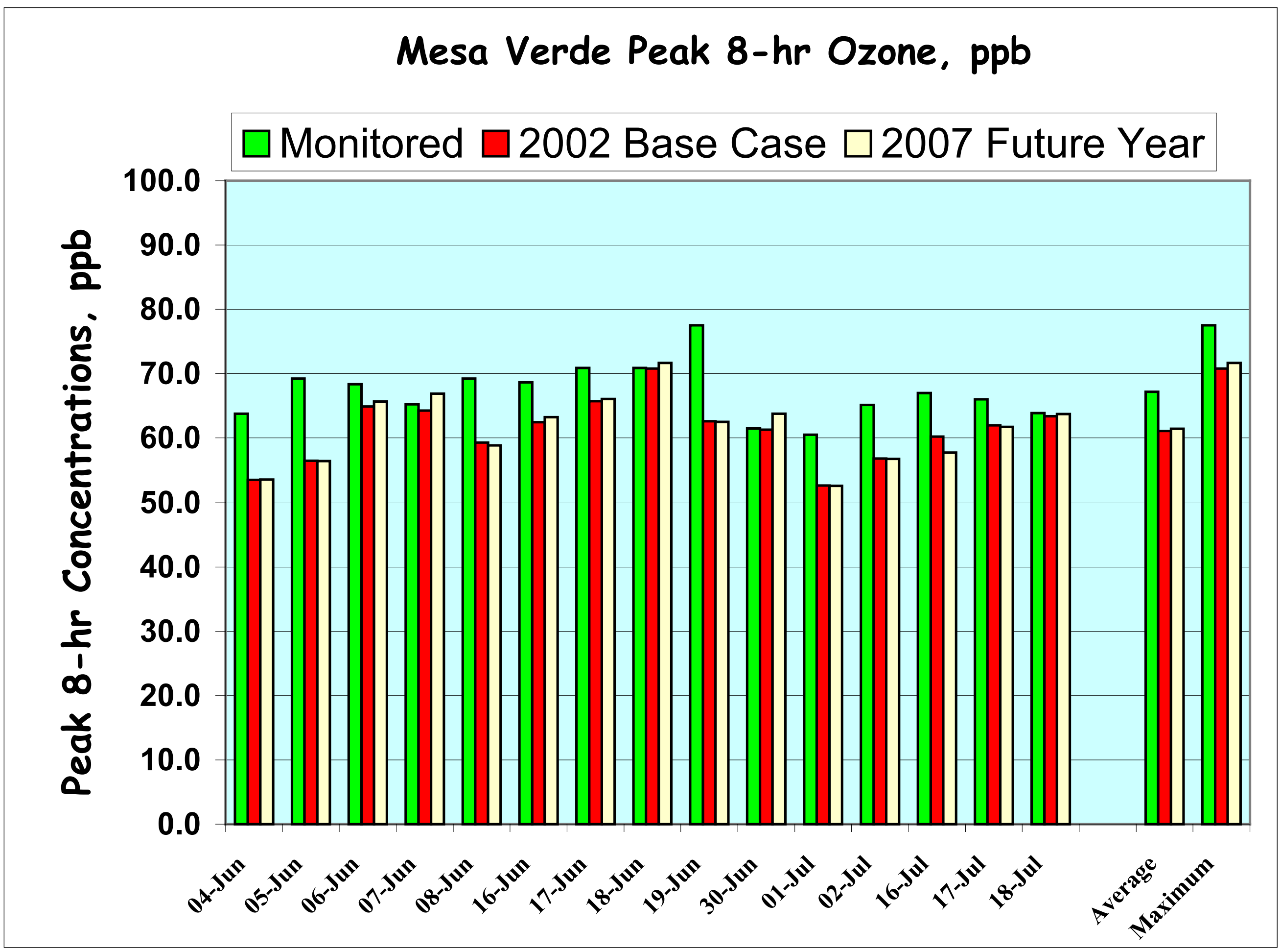


Figure 4-8. Daily Maximum 8-hr Ozone Predictions at Mesa Verde.

5.0 8-HR OZONE ATTAINMENT DEMONSTRATION

This chapter presents photochemical modeling results suggesting that that San Juan County and the surrounding areas in Northern New Mexico and Southwestern Colorado are expected to remain in attainment of the 8-hr ozone NAAQS by the year 2007 by a substantial margin.

5.1 Attainment Demonstration Methodology

The EPA draft guidance for 8-hour ozone modeling (EPA, 1999) recommends specific procedures for using photochemical modeling results in a *relative fashion* to scale monitored 8-hour ozone Design Values (DVs) at individual regulatory monitoring sites in a region in order to estimate, via modeling, whether future-year 8-hour ozone concentrations will achieve or exceed the National Ambient Air Quality Standard (NAAQS). Consistent with the San Juan ozone modeling protocol, we used these procedures to estimate 2007 8-hour ozone Design Values at each of the five regulatory monitors in the Four Corners/San Juan Basin region based on the estimated 2007 emission levels and associated CAMx model predictions of ozone in the region.

A robust attainment demonstration analysis was performed based on four discrete modeling episodes and a total of 15 modeling days. As discussed in the San Juan modeling protocol and episode selection report (Tesche et al., 2003a), the 4 June-19 July 2002 Super Summer '02 episode and the four embedded 8-hr ozone modeling episodes had the following advantages:

> The daily maximum 8-hr ozone concentrations at the Substation and Bloomfield monitors in New Mexico during these four episodes were typically quite close to the current (2001-2003) 8-hr Design Values (DVs) in the region (~ 74-75 ppb);

> All four episodes fall within the most recent year (2002) available at the time the EAC photochemical modeling study began; accordingly, the emissions estimates developed for these episodes were based on the most recent, representative emissions conditions in the region;

> All of the episodes were multiple-day in nature and a variety of meteorological conditions and potential source-receptor conditions were represented by the collection of 15 modeling days; and

> A sufficient number of days would be modeled such that EPA's 8-hr Attainment Test could be applied at the Substation and Bloomfield monitors in New Mexico and other regulatory monitors in southwestern Colorado.

The 2002 Base Case and 2007 Baseline emission scenario modeling results presented in the two preceding chapters were used in a relative fashion to estimate future 8-hour ozone Design Value (DVF) in the Four Corners Region. This was done through the calculation of a Relative Reduction Factor (RRF) defined as the ratio of the estimated 8-hour ozone concentrations from the 2007 emission scenario to the modeled 2002 Base Case. Following EPA methodology, the RRF is used to scale the current year measured Design Value (DVC) at each regulatory monitoring station in order to develop an estimate of the future-year (2007) 8-hour ozone Design Value (DVF). The relationship is:

DVF = DVC x RRF

The RRF is calculated using the maximum 8-hour ozone concentrations in the 'neighborhood' of each regulatory monitoring station in the 2002 Base Case and 2007 Baseline CAMx simulations. We note that the precise definition of 'neighborhood' is somewhat arbitrary. Following current EPA guidance for ozone SIP studies employing a 4 km grid nest (EPA, 1999, pg. 38), we assumed that the neighborhood around the Four Corners monitors was adequately characterized by an array of 7 x 7 grid cells encompassing the monitor.[1] With two minor exceptions identified below, we followed EPA's draft 8-hour modeling guidance to estimate the future-year 8-hour ozone Design Values for the Four Corners region under the conditions of the assumed 2007 Baseline emissions scenario.

5.2 Current 8-Hr Design Values

The current year 8-hour ozone Design Value (DVC) for the five stations in the Four Corners region were based on analysis of the most recent data from the 2001-2003 three-year period. The 8-hr DVs for the region are:

Monitor	2001-2003 Measured DV
Substation	74.7 ppb
Bloomfield	74.3 ppb
Bondad	57.0 ppb
Ignacio	59.7 ppb
Mesa Verde	67.3 ppb

Thus, the highest current regulatory DV in the region is 74.7 ppb at the Substation monitor. Largely on the basis of these results and similar results elsewhere in New Mexico and the systematic downward trend in 8-hr ozone DVs in the region over the past several years, on 3 December 2002, the EPA formally announced it's intention to declare San Juan County (as well as all other New Mexico counties) to be in attainment of the new 8-hr NAAQS (Green, 2003). As shown next, this photochemical modeling results for all four San Juan episodes strongly corroborate this finding by EPA.

5.3 Estimated Year 2007 8-hr Ozone Design Values

Table 5-1 lists the:

> Measured 2001-2003 8-hr ozone design values at the Bloomfield, Substation, Ignacio, Bondad, and Mesa Verde monitors;

> Measured daily maximum 8-hr ozone concentrations at the five Four Corners region regulatory monitors;

> Modeled 2002 daily maximum 8-hr ozone concentrations in the 'neighborhood' of the

[1] Our examination of other neighborhood definitions (see for example, Tesche et al., 2003e) reveals that the attainment demonstration results are insensitive to the precise definition of 'neighborhood'. Arrays of 7 x 7 grid cells, for example, yield essentially the same results as 6 x 6 or 9 x 9 arrays.

monitors; and

> Modeled 2007 daily maximum 8-hr ozone concentrations in the 'neighborhood' of the monitors;

> Modeled 2007-2002 Relative Reduction Factors (RRFs) on a day-by-day basis for each monitoring station.

The final column in Table 5-1 and Figure 5-1 present the overall findings of the San Juan EAC attainment demonstration analysis. For each monitoring station, we have estimated the modeled 2007 DV based on the average RRF across all 15 modeling days. These episode composite RRFs are all very close to 1.0 and range from 0.989 to 1.001. The product of these composite RRFs and the measured 2001-2003 DV are listed in the third column below. The 2007 DV's range from a low of 56.34 ppb at Ignacio to a maximum of 74.78 ppb at Bloomfield.

Monitor	**Meas. DV**	**2007 DV**	**Max DV**
Substation	74.7 ppb	72.87 ppb	75.00 ppb
Bloomfield	74.3 ppb	74.78 ppb	78.51 ppb
Bondad	57.0 ppb	58.88 ppb	60.03 ppb
Ignacio	59.7 ppb	56.34 ppb	57.51 ppb
Mesa Verde	67.3 ppb	67.27 ppb	68.77 ppb

EPA guidance suggests that the foregoing analysis be performed only for those monitors for which the base year (2002) modeled ozone concentrations in the neighborhood of a monitor exceed 70 ppb. However, given the systematically low 8-hr peak ozone values in the region, there were only three days for which values above 70 ppb were predicted: 18 June (72.53 at Mesa Verde); 19 June (70.13 ppb at Ignacio); and 30 June (71.44 ppb at Bloomfield). To address this situation, we calculated the above 2007 DV's in two ways. First, as noted, we used the average RRF's over all 15 modeling days as previously indicated. Alternatively, we calculated a "Maximum 2007 DV" based on the highest daily RRF calculated in Table 5-1 for each monitor. These results are also listed above. Clearly, regardless of which procedure one used to estimate an RRF, *the NAAQS of 84 ppb is met at all stations in the Four Corners/San Juan Basin by a substantial margin*.

WE note two minor two deviations from EPA's draft guidance in our computational methodology. First, EPA's guidance proposes that the average values across the different days for the 2002 and 2007 emission scenarios be rounded to the nearest ppb prior to calculating the RFF. However, this procedure unnecessarily loses precision and yields step-function RRFs that are counter-intuitive. Second, EPA's guidance recommends rounding the RRFs to two significant figures to the right of the decimal place, whereas we use three. Again we believe this is an unnecessary loss of precision. However, in the case of the San Juan EAC, these computational issues make little difference; the modeled 8-hr ozone values by any method examined still fall well below the federal standard.

Table 5-1. Eight-Hour Design Value Projections for 2007 for the Four San Juan EAC Episodes

Monitoring Location	Obs DV 01-'03	04-Jun 155	05-Jun 156	06-Jun 157	07-Jun 158	08-Jun 159	16-Jun 167	17-Jun 168	18-Jun 169	19-Jun 170	30-Jun 181	01-Jul 182	02-Jul 183	16-Jul 197	17-Jul 198	18-Jul 199	AVG All	2007 DV
Measured Daily Maximum 8-hr Ozone Concentration (ppb)																		
Bloomfield	74.3	64.25	80.63	69.88	68.63	71.00	71.50	74.25	73.50	76.75	63.00	61.38	78.75	68.13	74.50	79.17	71.69	
Substation	74.7	65.00	75.75	69.63	77.14	76.75	73.75	80.38	75.13	74.63	64.25	64.38	72.25	70.25	74.25	67.13	72.04	
Ignacio	59.7	54.88	60.88	61.25	53.88	61.00	56.88	61.75	60.50	60.50	54.75	56.75	56.13	50.75	54.00	60.38	57.62	
Bondad	57.0	45.50	50.75	51.50	44.50	48.88	53.50	60.38	57.13	58.25	45.63	47.75	49.75	46.13	49.25	53.75	50.84	
Mesa Verde	67.3	63.75	69.25	68.38	65.25	69.25	68.63	70.88	70.88	77.50	61.50	60.50	65.13	67.00	66.00	63.88	67.19	
2002 Modeled Daily Maximum 8-hr Ozone in 7 x 7 Cell Neighborhood (ppb)																		
Bloomfield	74.3	56.59	63.41	63.97	66.32	60.39	64.83	66.72	68.17	68.26	71.44	66.62	62.82	60.12	65.18	63.27	64.54	
Substation	74.7	53.71	61.55	62.84	62.43	58.34	63.55	64.71	67.27	64.99	68.66	55.29	58.92	60.83	64.45	57.77	61.69	
Ignacio	59.7	57.84	61.49	67.38	69.15	65.26	63.69	67.03	69.96	70.13	63.05	53.51	54.89	57.96	61.63	63.13	63.07	
Bondad	57.0	56.43	61.48	66.62	68.26	64.07	63.06	66.82	69.70	68.71	64.56	54.00	57.95	60.35	62.66	64.77	63.30	
Mesa Verde	67.3	53.56	56.50	64.89	66.56	59.28	62.45	65.71	72.53	62.61	62.42	52.67	56.84	60.22	61.97	63.44	61.44	
2007 Modeled Daily Maximum 8-hr Ozone in 7 x 7 Cell Neighborhood (ppb)																		
Bloomfield	74.3	56.77	63.69	63.84	66.88	60.26	64.75	66.83	68.18	66.69	72.12	55.78	62.88	57.82	62.69	60.18	63.29	
Substation	74.7	53.96	64.21	63.14	62.92	58.20	64.00	64.99	67.14	64.20	72.16	54.33	58.90	58.98	63.22	56.43	61.78	
Ignacio	59.7	58.07	60.87	66.37	68.63	65.01	62.18	66.23	68.44	70.52	63.06	52.75	53.89	56.72	59.65	60.83	62.21	
Bondad	57.0	56.94	60.97	66.37	67.97	63.96	61.74	66.23	68.41	69.05	64.64	53.31	56.91	59.11	60.93	62.02	62.57	
Mesa Verde	67.3	53.58	56.47	65.65	66.90	58.83	63.22	66.05	71.68	62.53	63.78	52.60	56.82	57.77	61.70	63.73	61.42	
2007-2002 Relative Reduction Factors By Station and Day																		
Bloomfield	74.3	1.003	1.004	0.998	1.008	0.998	0.999	1.002	1.000	0.977	1.009	0.837	1.001	0.962	0.962	0.951	0.981	72.87
Substation	74.7	1.005	1.043	1.005	1.008	0.998	1.007	1.004	0.998	0.988	1.051	0.983	1.000	0.970	0.981	0.977	1.001	74.78
Ignacio	59.7	1.004	0.990	0.985	0.992	0.996	0.976	0.988	0.978	1.006	1.000	0.986	0.982	0.979	0.968	0.964	0.986	58.88
Bondad	57.0	1.009	0.992	0.996	0.996	0.998	0.979	0.991	0.982	1.005	1.001	0.987	0.982	0.979	0.972	0.958	0.989	56.34
Mesa Verde	67.3	1.000	1.000	1.012	1.005	0.992	1.012	1.005	0.988	0.999	1.022	0.999	1.000	0.959	0.996	1.005	1.000	67.27

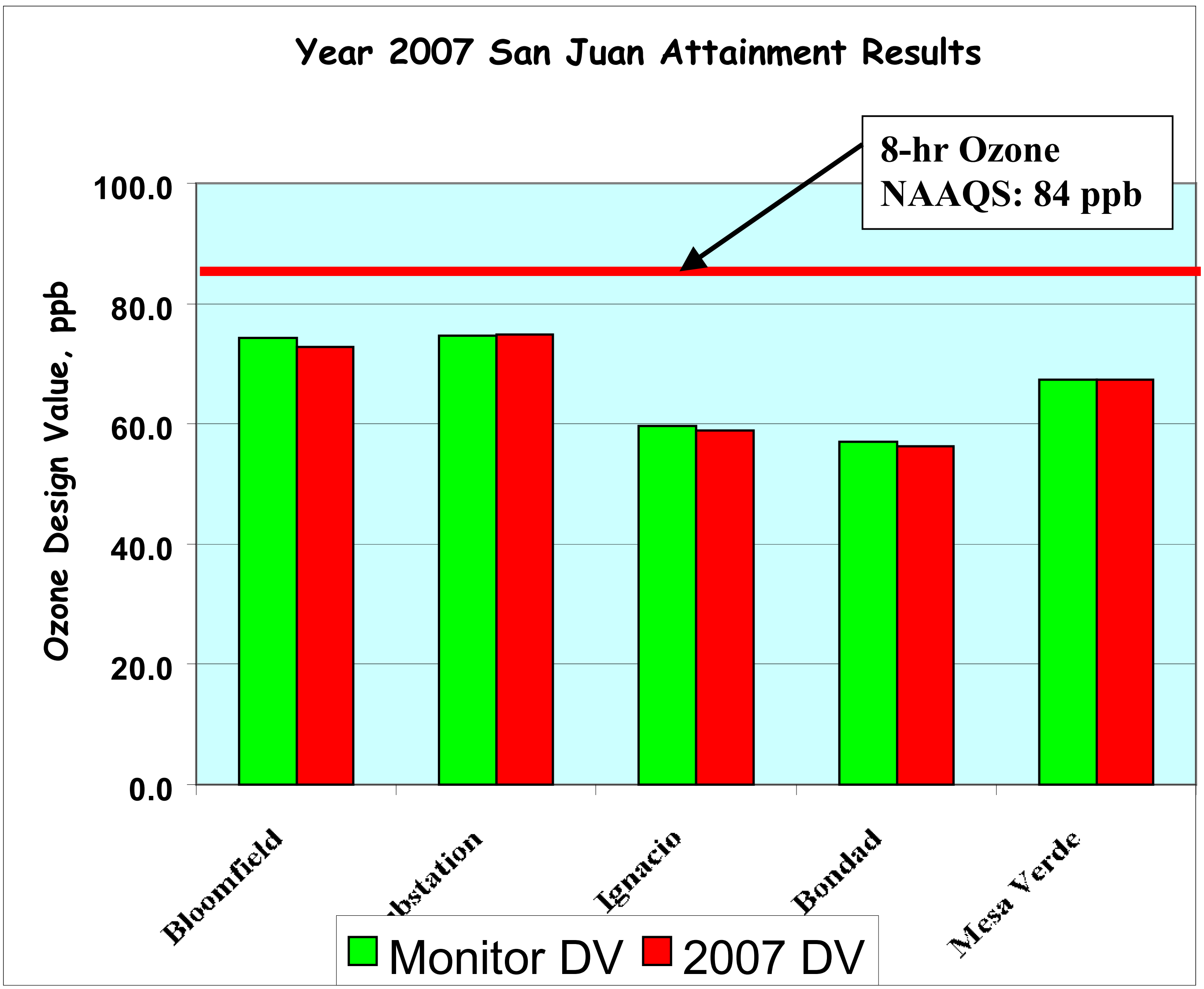


Figure 5-1. Final San Juan 8-hr EAC Ozone Attainment Demonstration Results.

6.0 SUMMARY AND CONCLUSIONS

This report describes the results of a photochemical modeling analysis carried out by Alpine Geophysics and ENVIRON International Corporation as part of the San Juan Early Action Compact (EAC) Study, described in detail in the modeling protocol by Tesche et al., (2003a). As part of this study, a state-of-science air quality modeling system was applied to four ozone episodes during a fifty (50) day long summer ozone period over the Four Corners/San Juan Basin region. Spanning the 4 June-23 July 2002 timeframe, these episodes included: (a) 4-8 June 2002; (b) 16-19 June 2002; (c) 30 June-2 July 2002; and (d) 16-18 July 2002. Nested meteorological and photochemical model simulations were performed consistent with draft EPA guidance (EPA, 1999).

6.1 Summary

The Alpine/ENVIRON study team successfully carried out an operational evaluation of the CAMx photochemical model for four San Juan 8-hr ozone episodes. We found that the model performed very well in simulating observed ozone concentrations. The level of accuracy and reliability of the modeling was judged sufficient for use in estimating the likelihood of attainment of the new 8-hr ozone National Ambient Air Quality Standard (NAAQS) in the Four Corners Region. Based upon the successful evaluation of the CAMx modeling system for all four episodes, the model was used to simulate year 2007 baseline conditions to allow estimation of the 8-hr ozone 2007 Design Values (DV). These modeled Design Values were then compared directly with the ozone NAAQS to assess the likelihood that the region would attain the NAAQS in 2007.

6.2 Conclusions

6.2.1 Accuracy and Reliability of the CAMx Modeling System

The CAMx 8-hr ozone performance results exhibit a level of performance for all four episodes that was well within EPA's draft performance goals in all but a few cases. The results are quite consistent with model applications in other regions and are typically better than that encountered in a 'first time application' of a photochemical modeling system to a new region. With respect to the adequacy of the CAMx modeling and the suitability of the current base cases, we conclude that:

> The San Juan photochemical modeling activity clearly selected an appropriate regional photochemical model for use in this assessment;

> The CAMx modeling was carried out in a credible, well-documented manner that was consistent with current practice in regional photochemical modeling and the procedures commonly used in the application of this sophisticated model;

> The suite of evaluation procedures employed to test the CAMx model were comprehensive and consistent with EPA's recommended methods for both 1-hr and 8-hr ozone modeling;

> The data base available to test the CAMx model was extremely limited, precluding a number of meaningful, stressful tests of the model to ascertain whether it suffers

from internal, compensating errors; as a result, model testing was largely confined to an operational evaluation of hourly-average, ground-level ozone concentrations;

> Generally, the CAMx performance for surface 1-hr and 8-hr ozone concentrations are quite consistent with contemporary modeling experience and with EPA's suggested 8-hr ozone evaluation benchmarks; and

> None of the performance testing results conducted have revealed flaws in CAMx performance of such a magnitude as to clearly indicate the presence of errors that would render the model inappropriate for use, with proper cautions, in evaluating future year 8-hr ozone attainment or generalized emissions control scenarios.

Thus, from the model verification exercises we conclude that the CAMx bases cases for Episodes 1 through 4 may be used, with appropriate caution, to evaluate year 2007 baseline conditions, to examine model sensitivity to plausible VOC and/or NOx emissions reduction strategies, and to demonstrate attainment with the 8-hr ozone NAAQS.

6.2.2 Predicted Year 2007 Baseline Ozone Concentrations

Using project 2007 emissions inventories incorporation local and national emissions growth and control data were appropriate, we exercised the CAMx modeling system to predict year 2007 baseline 8-hr ozone levels on 15 days encompassing the four San Juan episodes. Examination of the year 2007 8-hr ozone modeling results revealed a very consistent picture. Changes are predicted to occur in daily maximum 8-hr ozone concentrations from 2002 to 2007 but these changes are generally very small (i.e., a few ppb) and are typically negative. That is, on most days, predicted peak ozone levels in 2007 in the neighborhood of the regulatory monitors decrease by a few ppb from year 2002 baseline levels. At the Substation and Bloomfield monitors in San Juan County, ozone increases occur on less than half the modeling days and these increases are limited to 0.1 ppb to 3.1 ppb (mean of 1.2 ppb.) The maximum 'neighborhood' 8-hr ozone concentrations for 2007 over all episodes are 72.1 ppb at Bloomfield, 72.2 ppb at Substation, 70.5 ppb at Ignacio, 69.1 ppb at Bondad , and 71.7 ppb at Mesa Verde. Beyond the immediate neighborhoods of these regulatory monitors but within the general Four Corners/San Juan Basin region, the future year 8-hr ozone concentrations were below 75 ppb on all fifteen modeling days.

6.2.3 Year 2007 8-hr Ozone Attainment Demonstration

Following EPA's draft guidance for 8-hour ozone attainment demonstrations, we calculated the current Design Values (DVs) at each regulatory monitor. Using the CAMx 2002 base case and 2007 future year modeling results, we also calculated relative reduction factors (RRFs) for all fifteen modeling days. The episode average RRFs were very close to unity, ranging from 0.989 to 1.001. The product of these composite RRFs and the measured 2001-2003 DV are listed in the third column below. The 2007 DV's range from a low of 56.34 ppb at Ignacio to a maximum of 74.78 ppb at Bloomfield.

Monitor	**Meas. DV**	**2007 DV**
Substation	74.7 ppb	72.87 ppb
Bloomfield	74.3 ppb	74.78 ppb
Bondad	57.0 ppb	58.88 ppb
Ignacio	59.7 ppb	56.34 ppb
Mesa Verde	67.3 ppb	67.27 ppb

We also estimated an upper bound on the 2007 DV at each monitor using the highest daily RRF calculated over the 15 days (see Table 5-1). Regardless of the procedure used to estimate the RRF at each station, *the NAAQS of 84 ppb was met at all stations in the Four Corners/San Juan Basin by a substantial margin*.

Thus, the photochemical modeling corroborates the analyses performed by NMED and EPA with the 8-hr measurement data, suggesting that the region will not violate the NAAQS in 2007. Given that: (a) the peak measured 2001-2003 DV in the region is 74.7 ppb at Substation , (b) the trends in 8-hr ozone in the region are declining, and (c) the peak modeled 2007 DV was 74.78 ppb at the Bloomfield, there is strong reason to believe that San Juan County as well as all other counties in the Four Corners Region will remain in attainment of the 8-hr NAAQS through 2007. Indeed, EPA has already formally stated the agency's intent (Green, 2003) to declare the region in attainment of the 8-hr standard based on current monitoring data. The results of the San Juan EAC photochemical study provides strong corroborative support for this decision.

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APPENDIX A:
DAILY MAXIMUM 8-HR OZONE CONCENTRATION FIELDS FOR FOUR SAN JUAN EAC EPISODES

This appendix presents the daily maximum 8-hr ozone concentrations for the principal days of each San Juan EAC modeling episodes. In the following figures, the modeled 8-hr concentrations are depicted according to the color code at the bottom of each figure. The measured 8-hr ozone concentrations at each monitoring station in the 4 km Four Corners Region domain are denoted by the solid black numeral. The statistics at the top of each page present the maximum, minimum, average, and grid total 8-hr ozone concentrations (in ppb) for each simulation day.

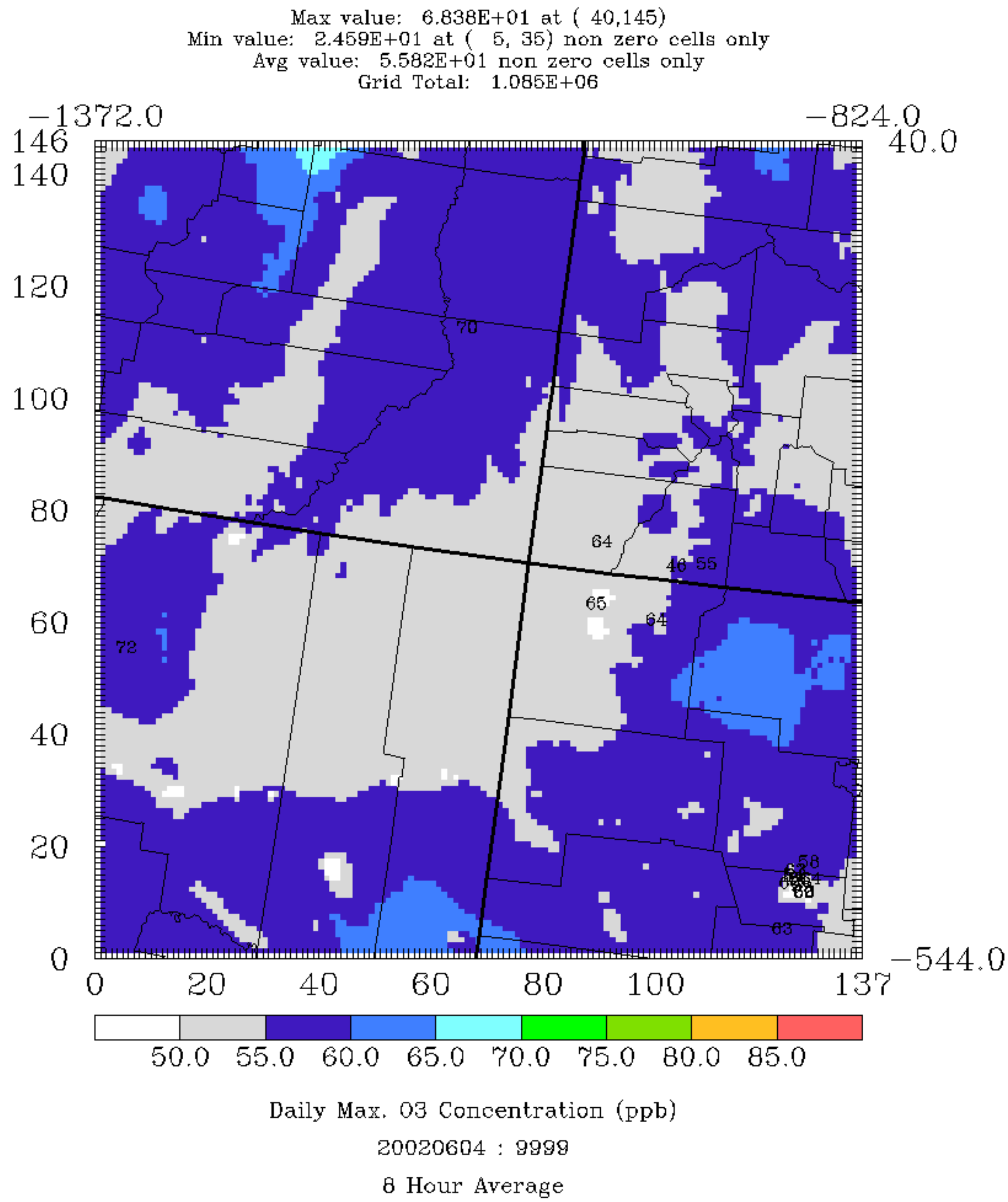

Figure A-1. Daily Maximum 8-hr Ozone Concentrations on 4 June 2007.

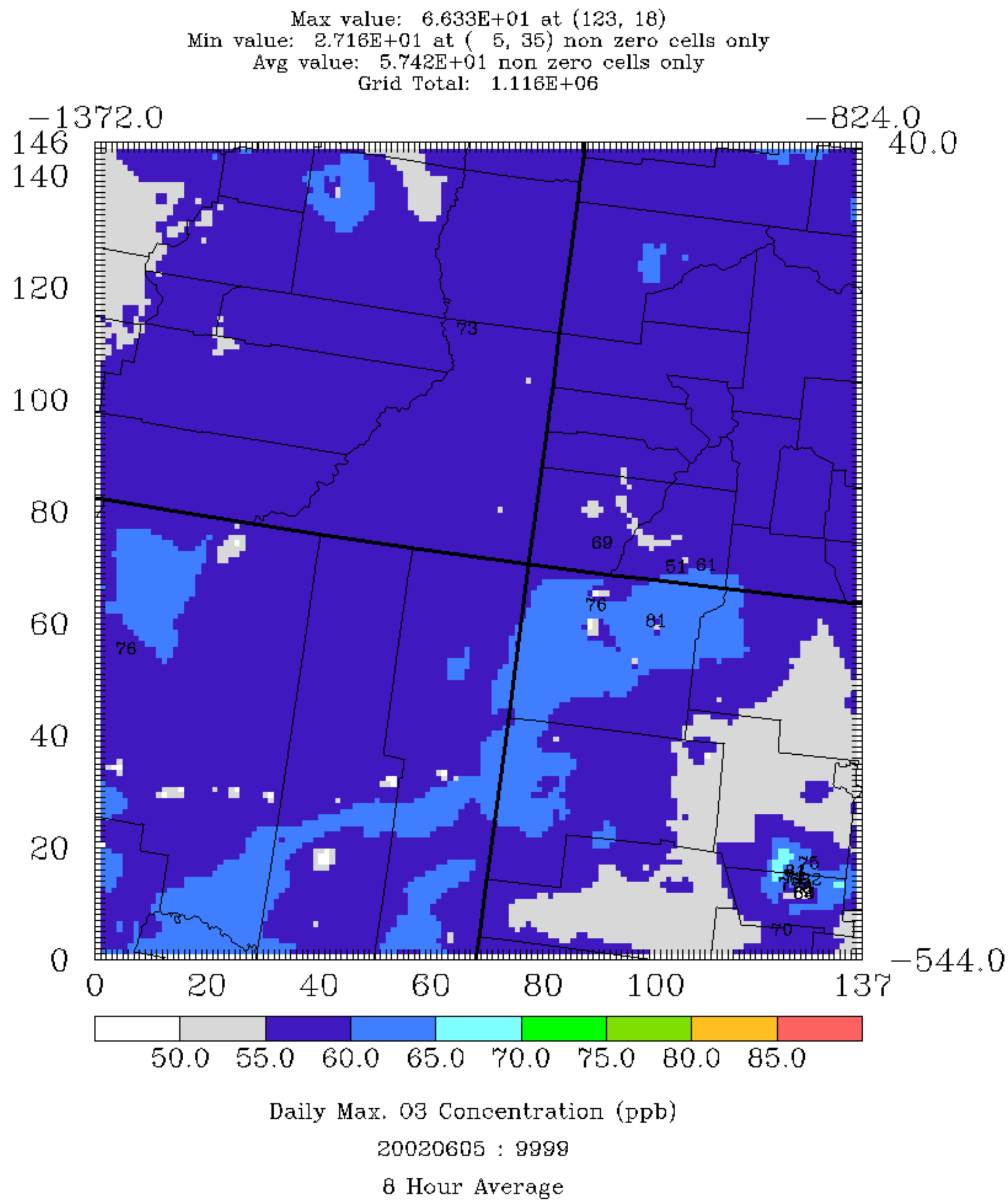

Figure A-2. Daily Maximum 8-hr Ozone Concentrations on 5 June 2007.

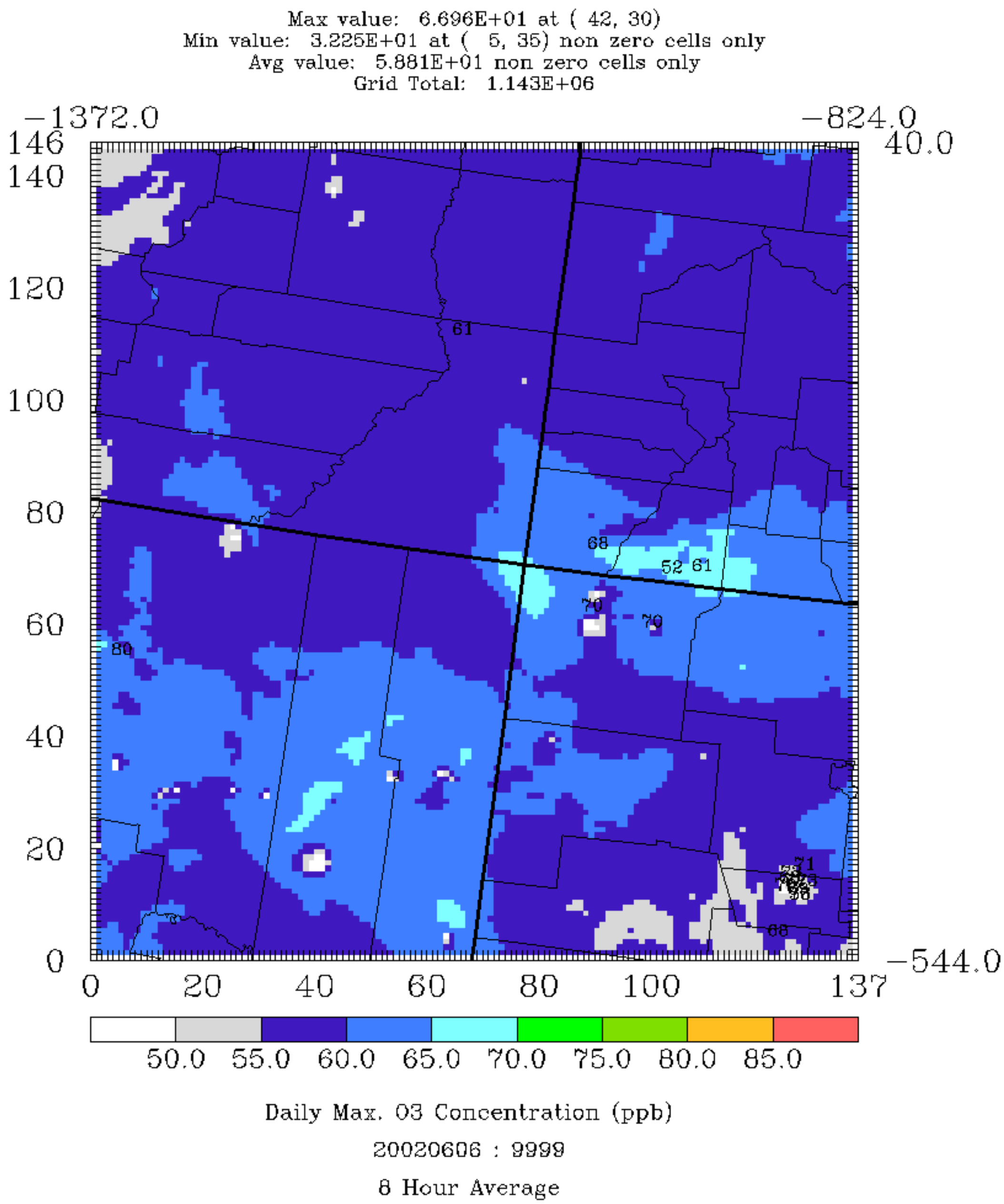

Figure A-3. Daily Maximum 8-hr Ozone Concentrations on 6 June 2007.

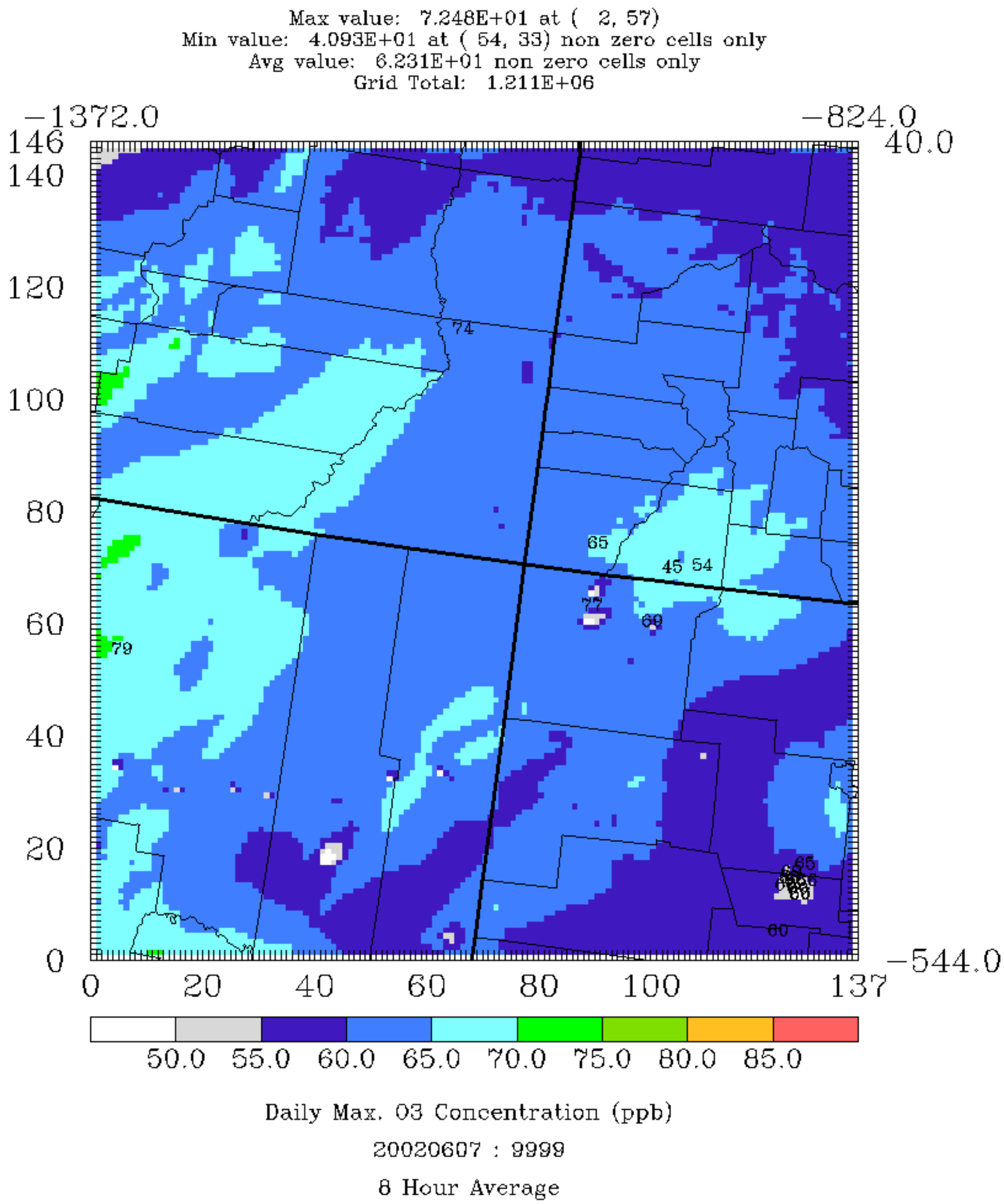

Figure A-4. Daily Maximum 8-hr Ozone Concentrations on 7 June 2007.

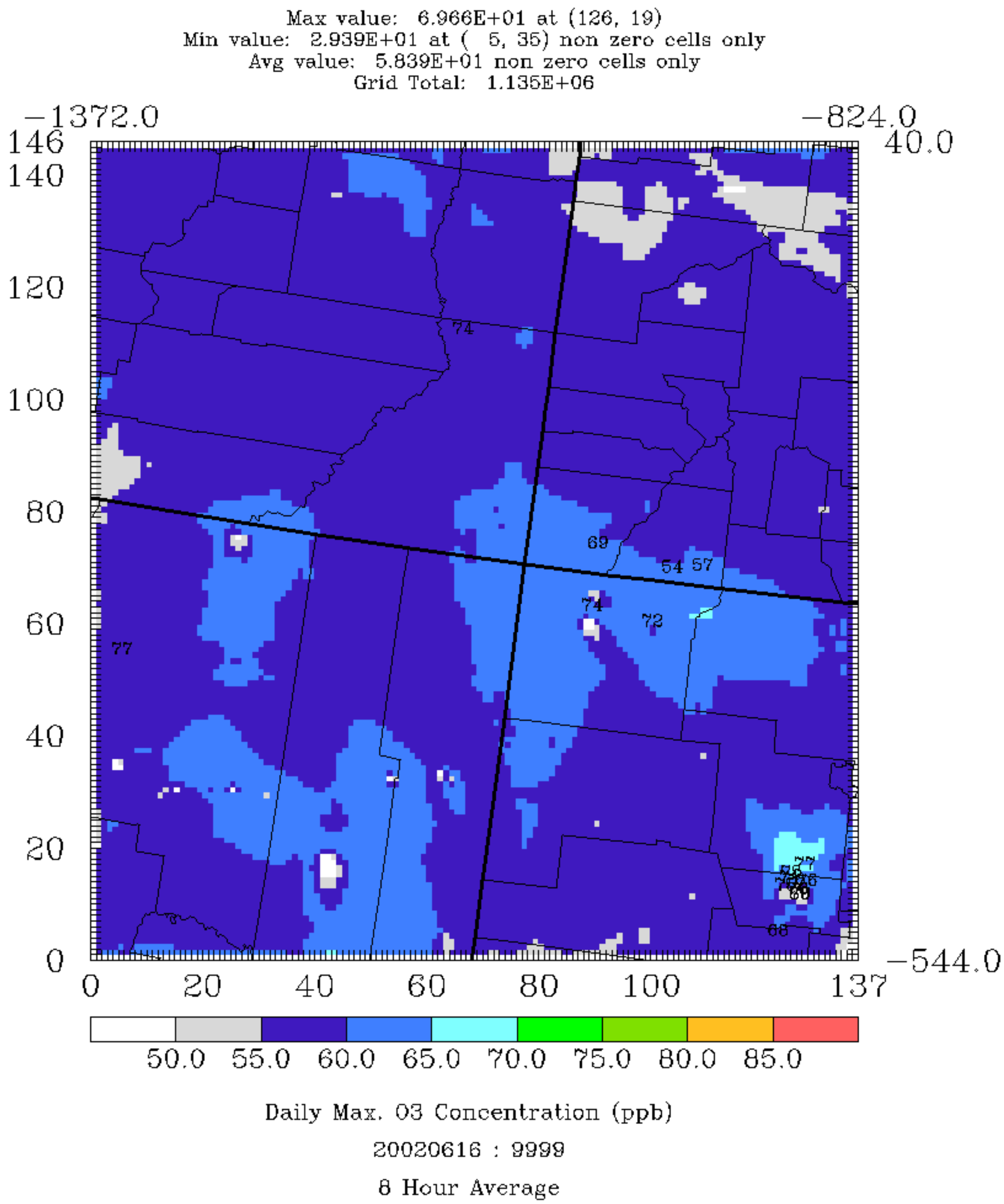

Figure A-5. Daily Maximum 8-hr Ozone Concentrations on 16 June 2007.

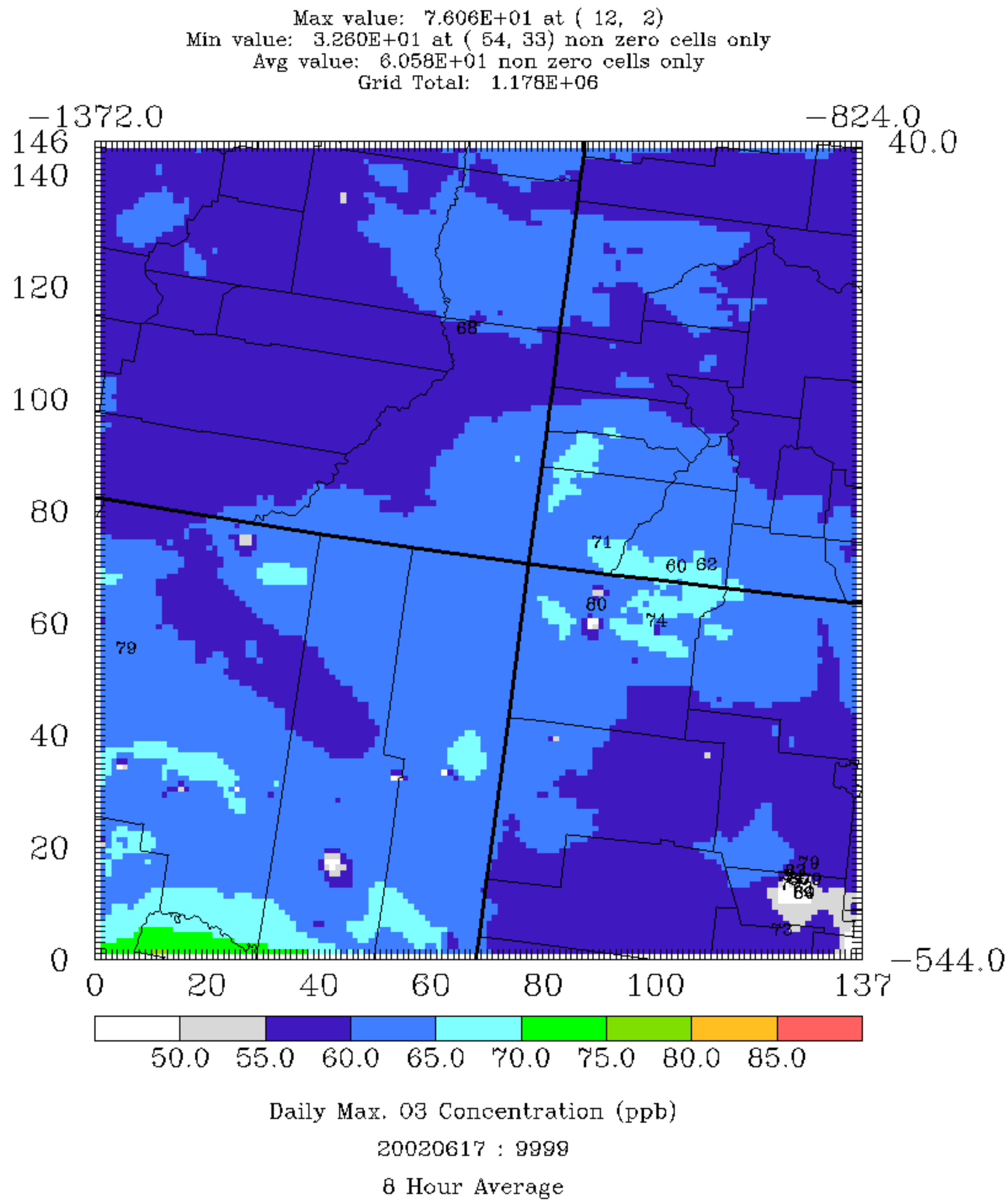

Figure A-6. Daily Maximum 8-hr Ozone Concentrations on 17 June 2007.

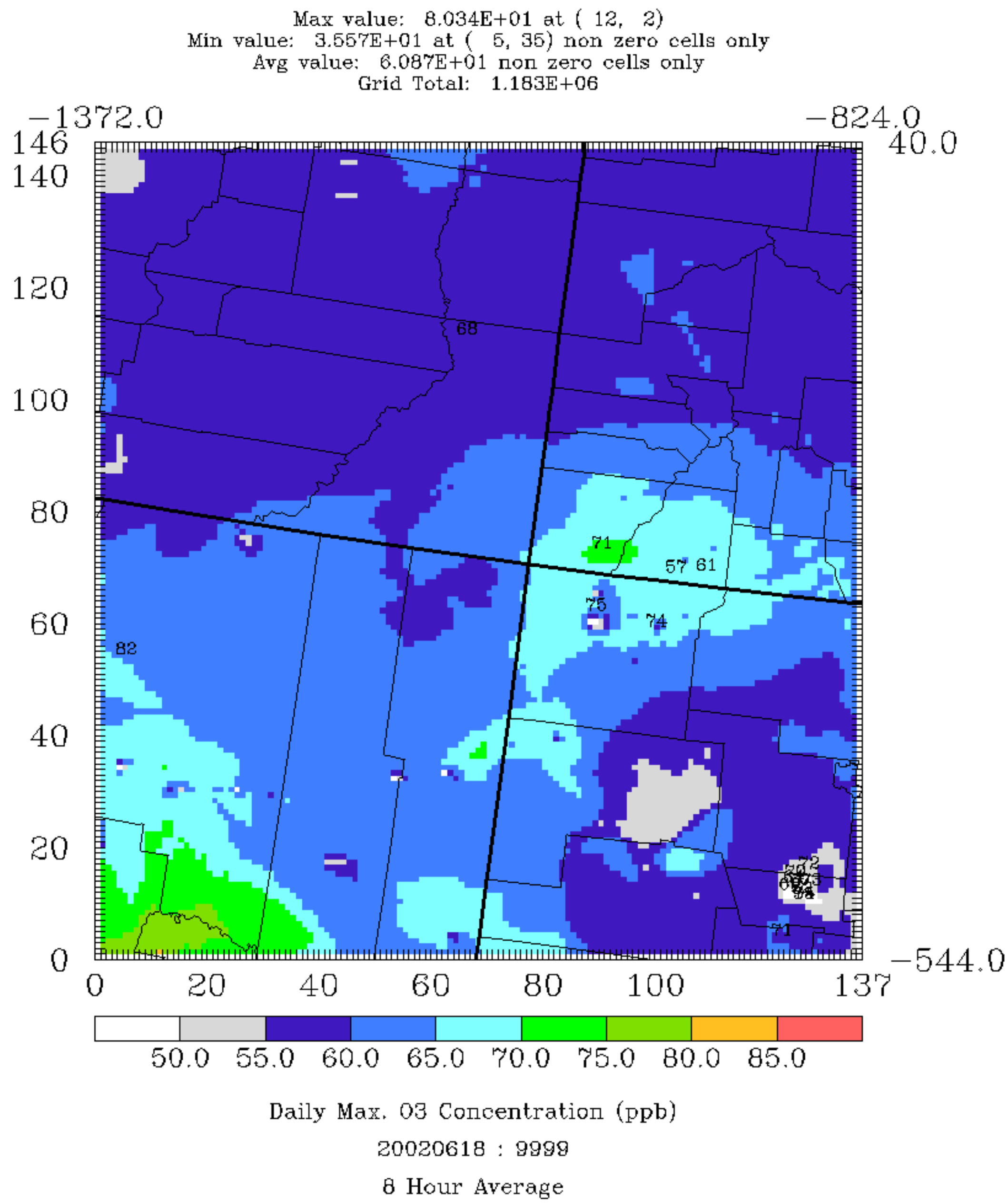

Figure A-7. Daily Maximum 8-hr Ozone Concentrations on 18 June 2007.

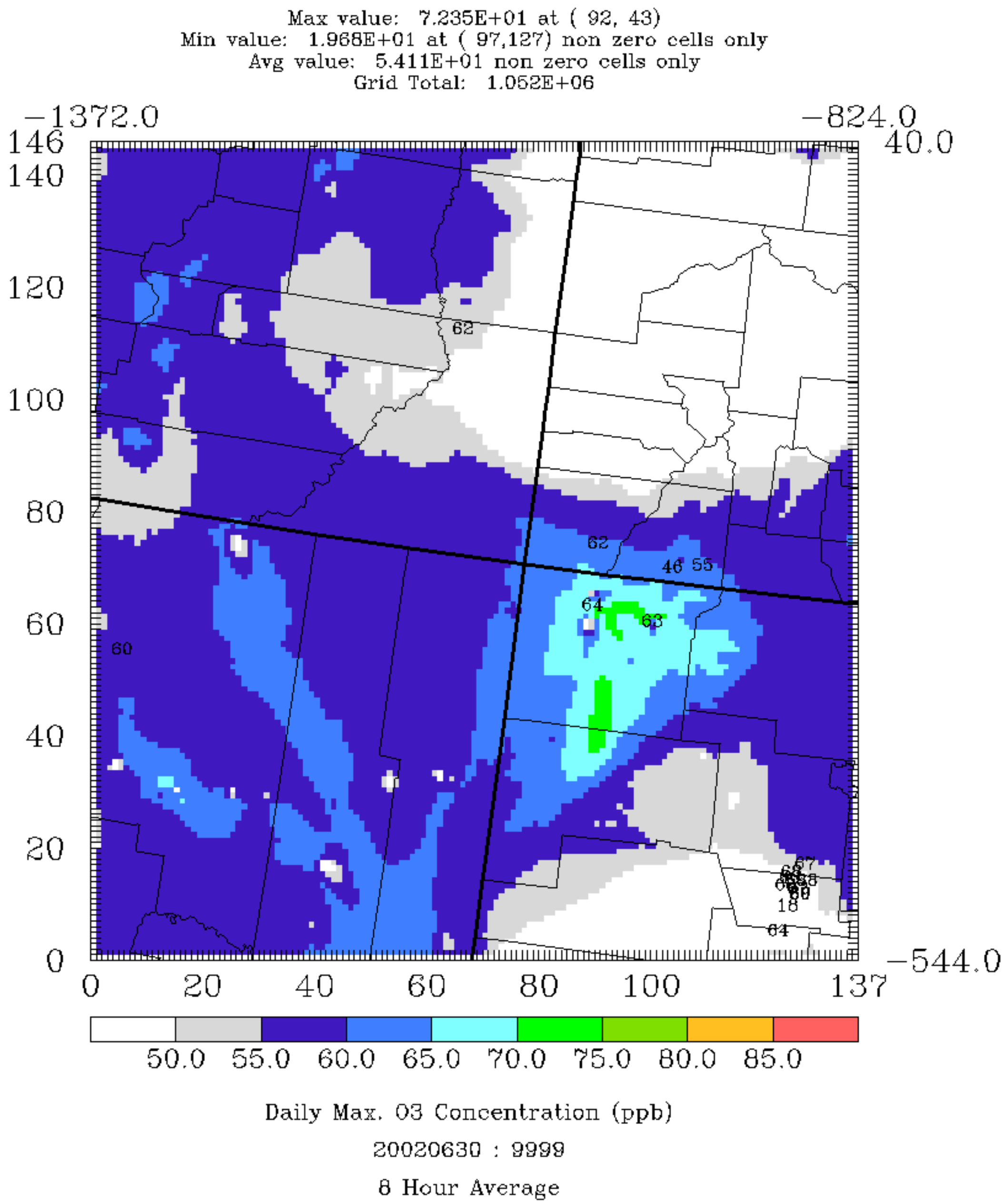

Figure A-8. Daily Maximum 8-hr Ozone Concentrations on 30 June 2007.

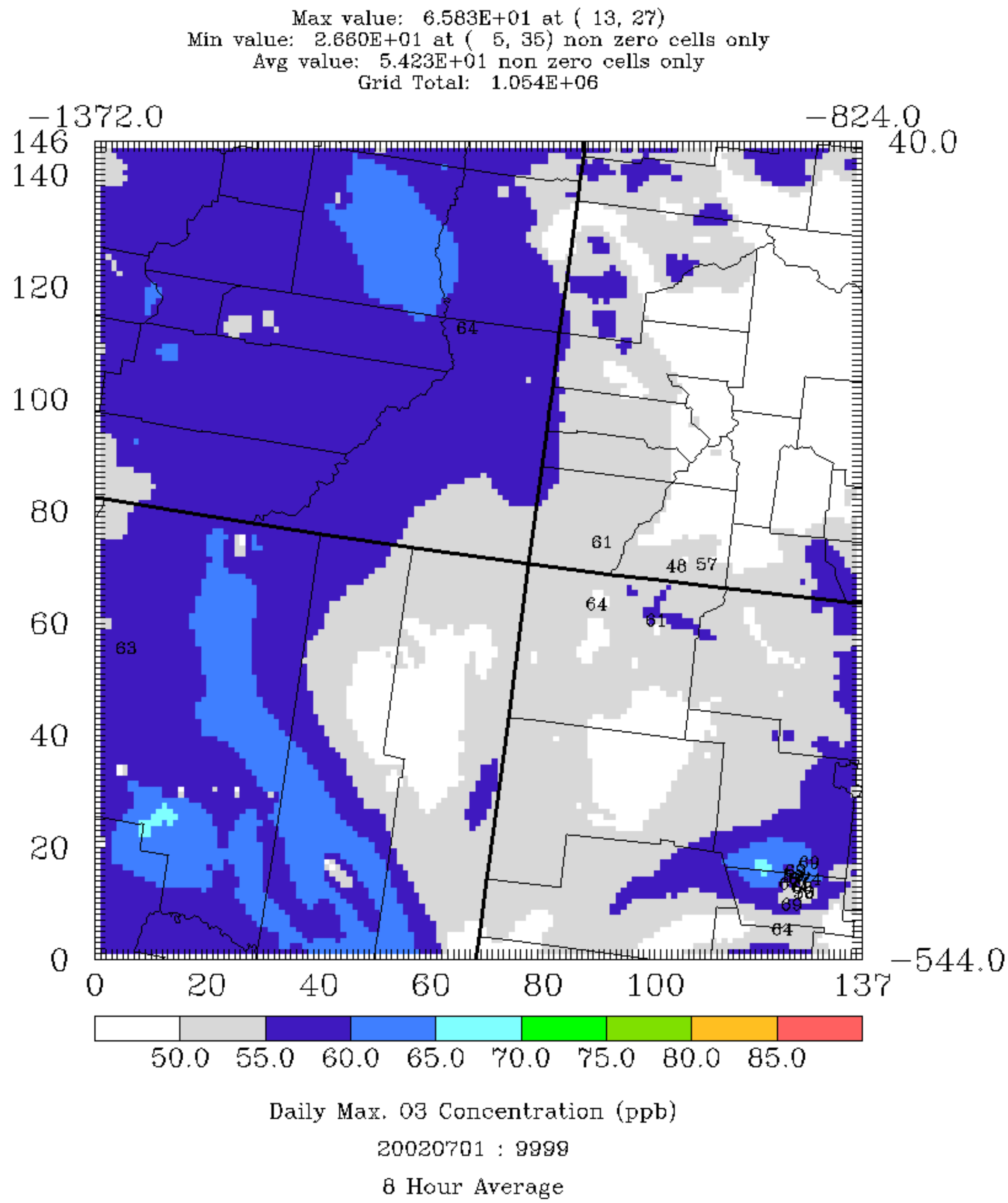

Figure A-9. Daily Maximum 8-hr Ozone Concentrations on 1 July 2007.

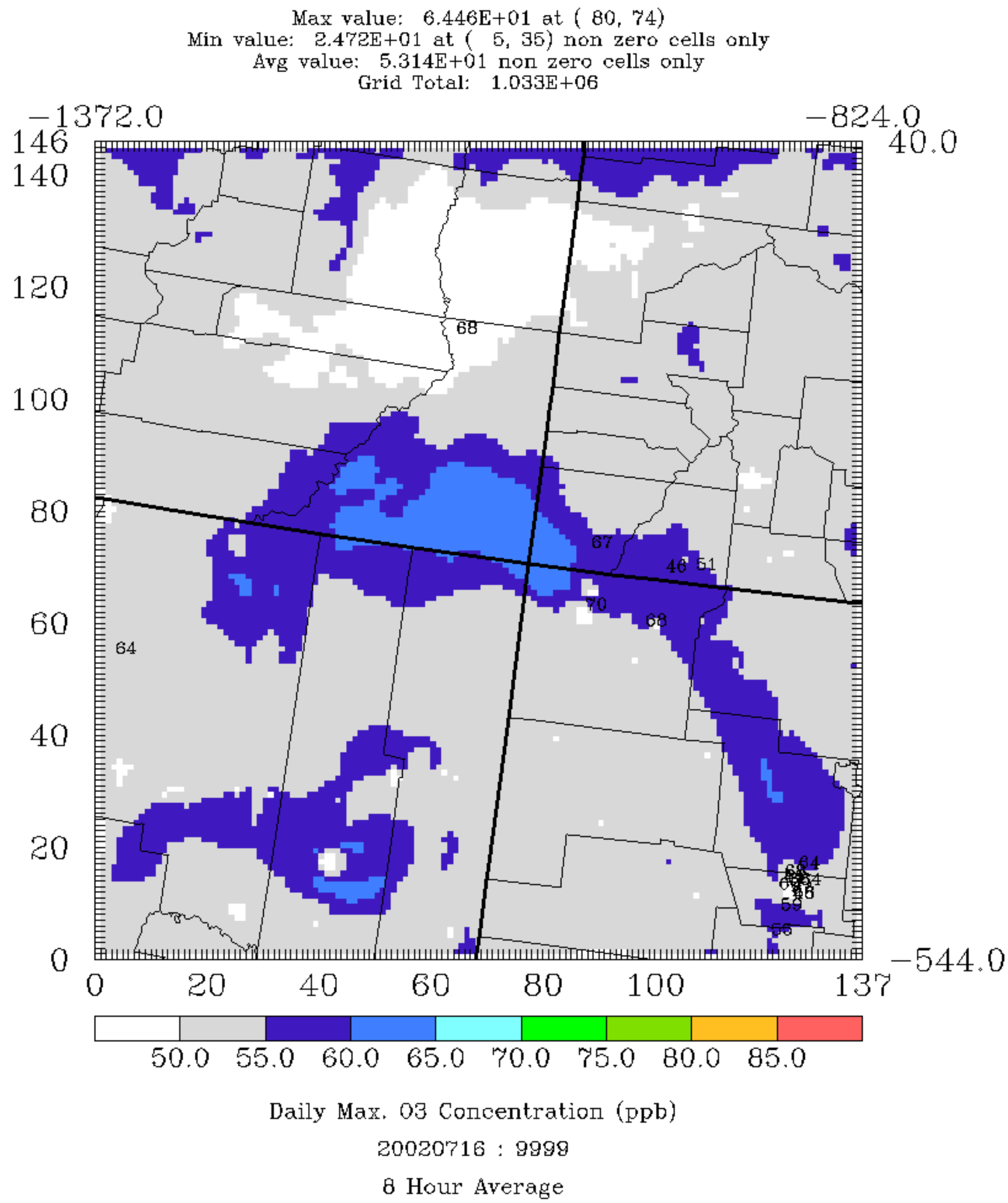

Figure A-10. Daily Maximum 8-hr Ozone Concentrations on 16 July 2007.

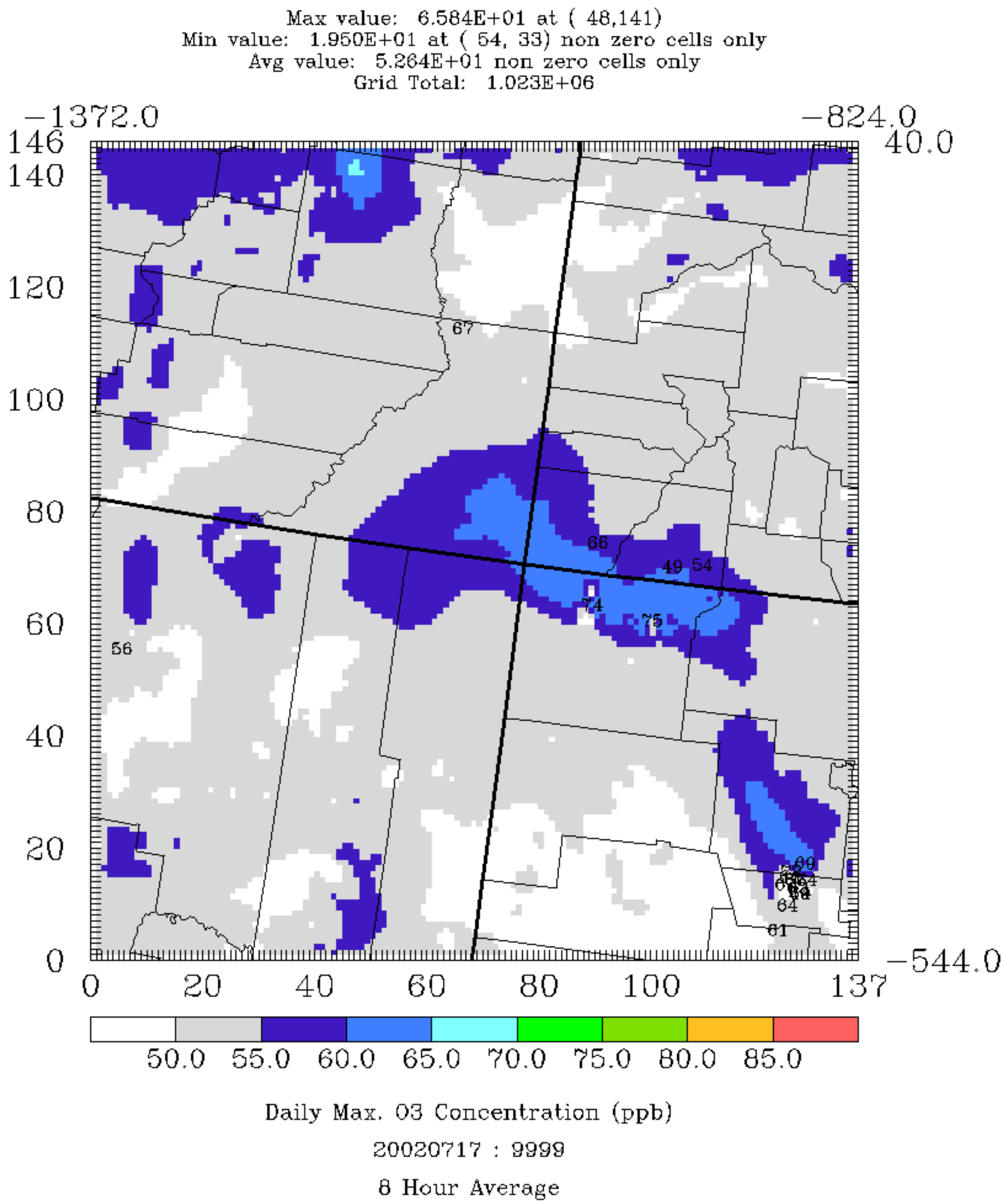

Figure A-11. Daily Maximum 8-hr Ozone Concentrations on 16 July 2007.

APPENDIX B:
DAILY MAXIMUM 8-HR OZONE CONCENTRATION DIFFERENCE FIELDS (2007 MINUS 2002) FOR FOUR SAN JUAN EAC EPISODES

This appendix presents daily maximum 8-hr ozone residual concentrations fields for the principal days of each San Juan EAC modeling episode. These residual concentration plots were constructed by subtracting the year 2002 results from the year 2007 baseline results. Thus, if ozone is predicted to be reduced in the year 2007, the concentration change would be negative. If ozone goes up in 2007, the change would be positive. In the figures, the modeled 8-hr concentration residuals are depicted according to the color code at the bottom of each figure. The statistics at the top of each page present the maximum, minimum, average, and grid total 8-hr ozone concentration residual (in ppb) for each simulation day.

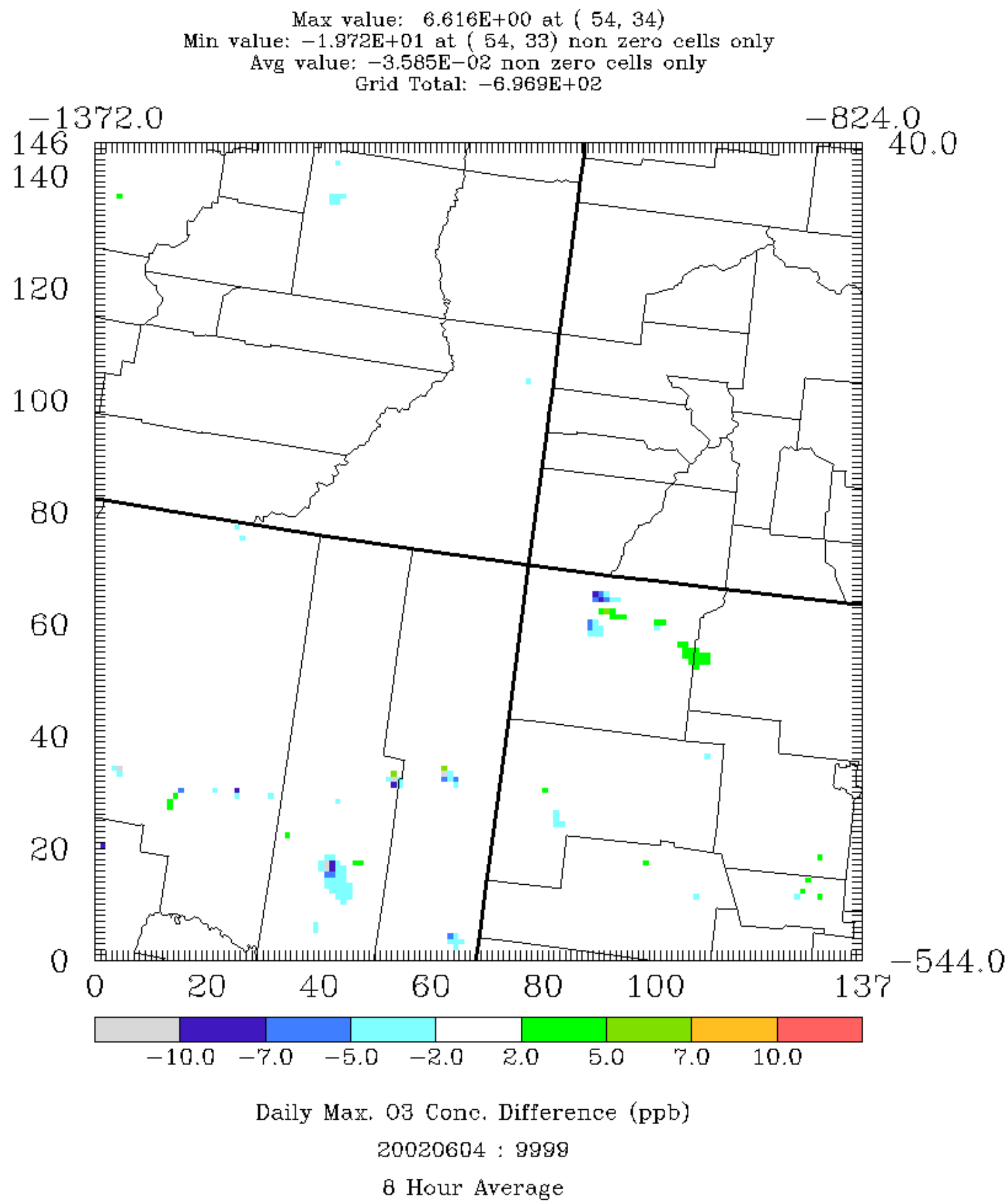

Figure B-1. Daily Maximum 8-hr Ozone Residuals (2007 minus 2002) on 4 June 2007.

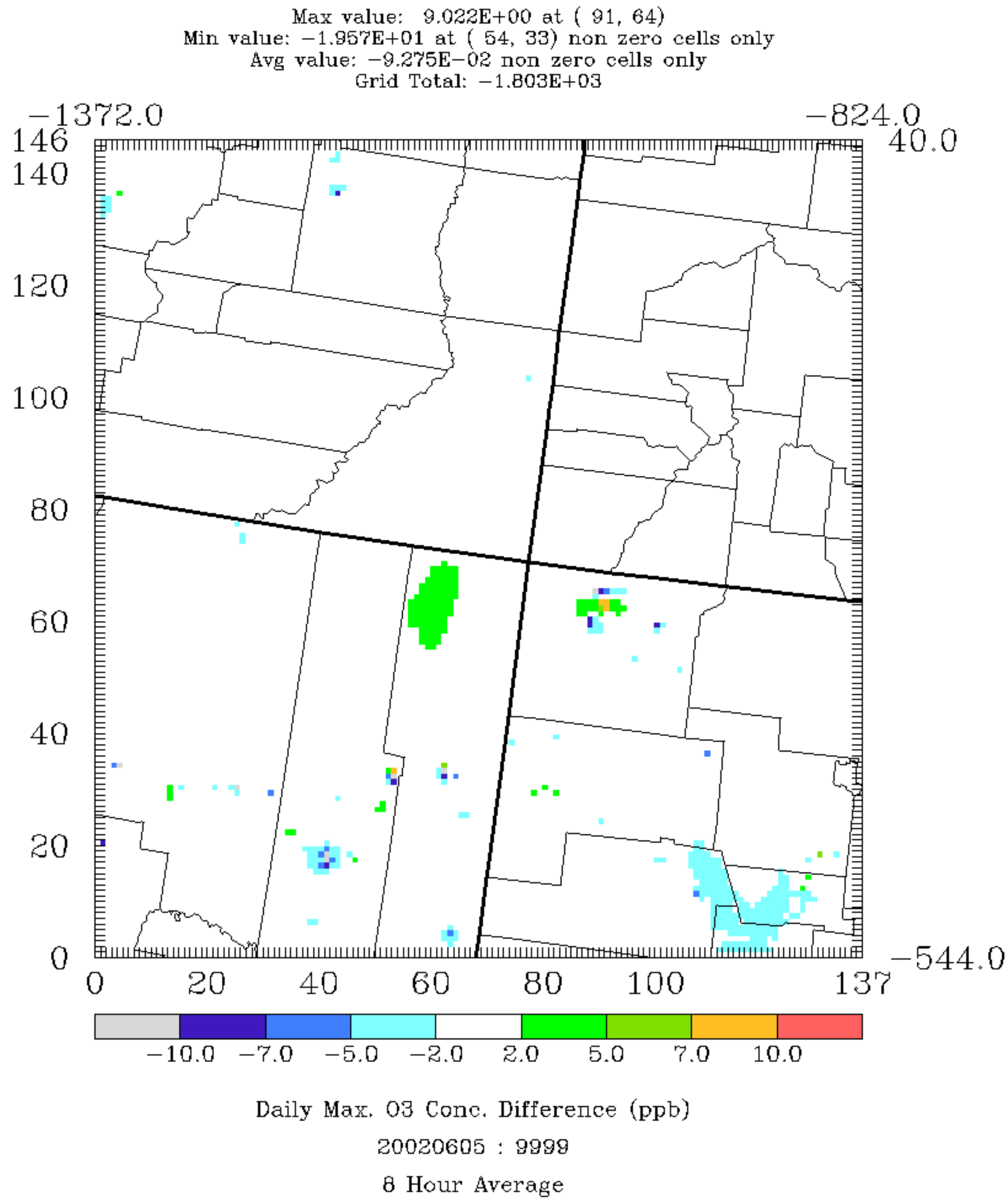

Figure B-2. Daily Maximum 8-hr Ozone Residuals (2007 minus 2002) on 5 June 2007.

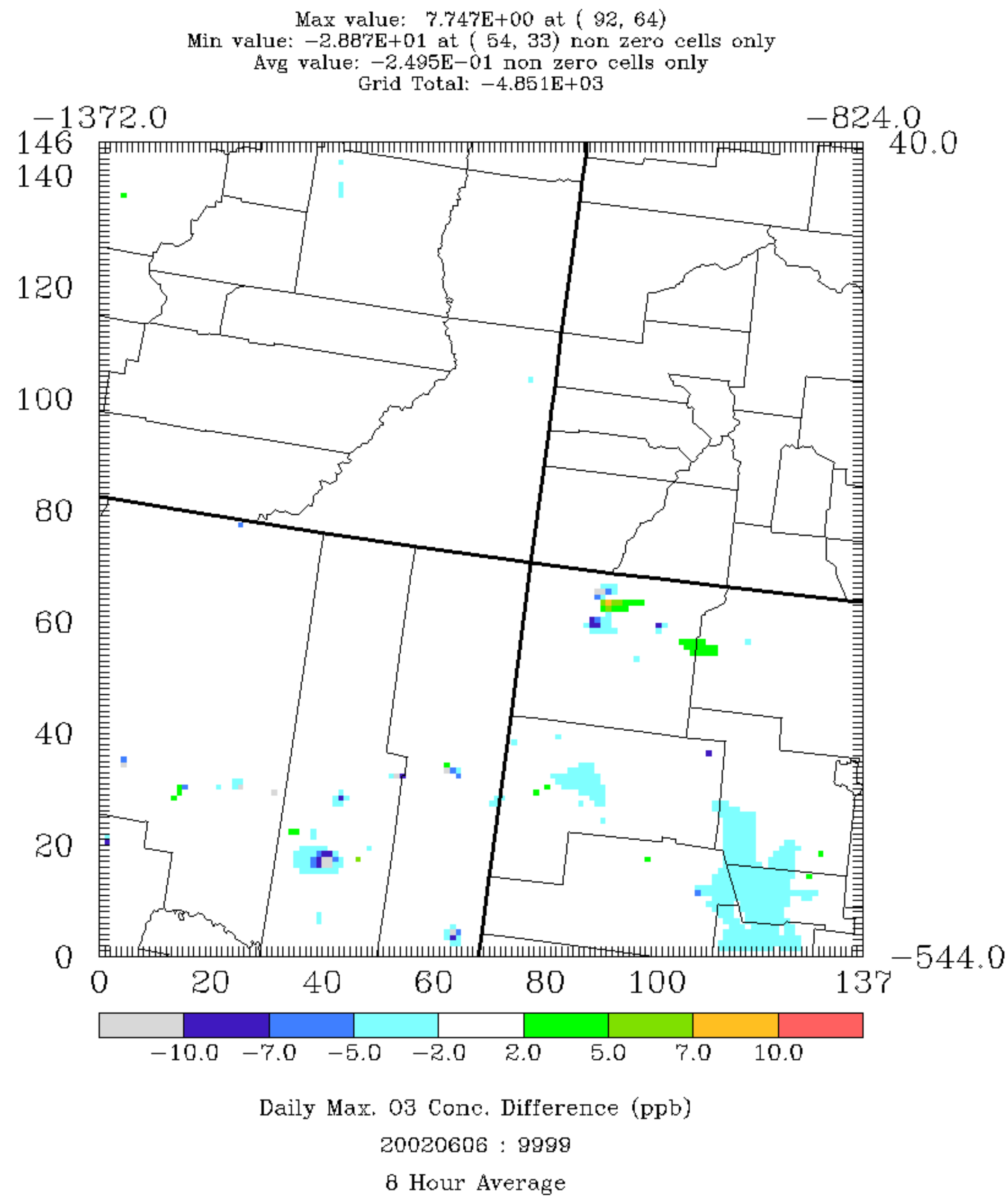

Figure B-3. Daily Maximum 8-hr Ozone Residuals (2007 minus 2002) on 6 June 2007.

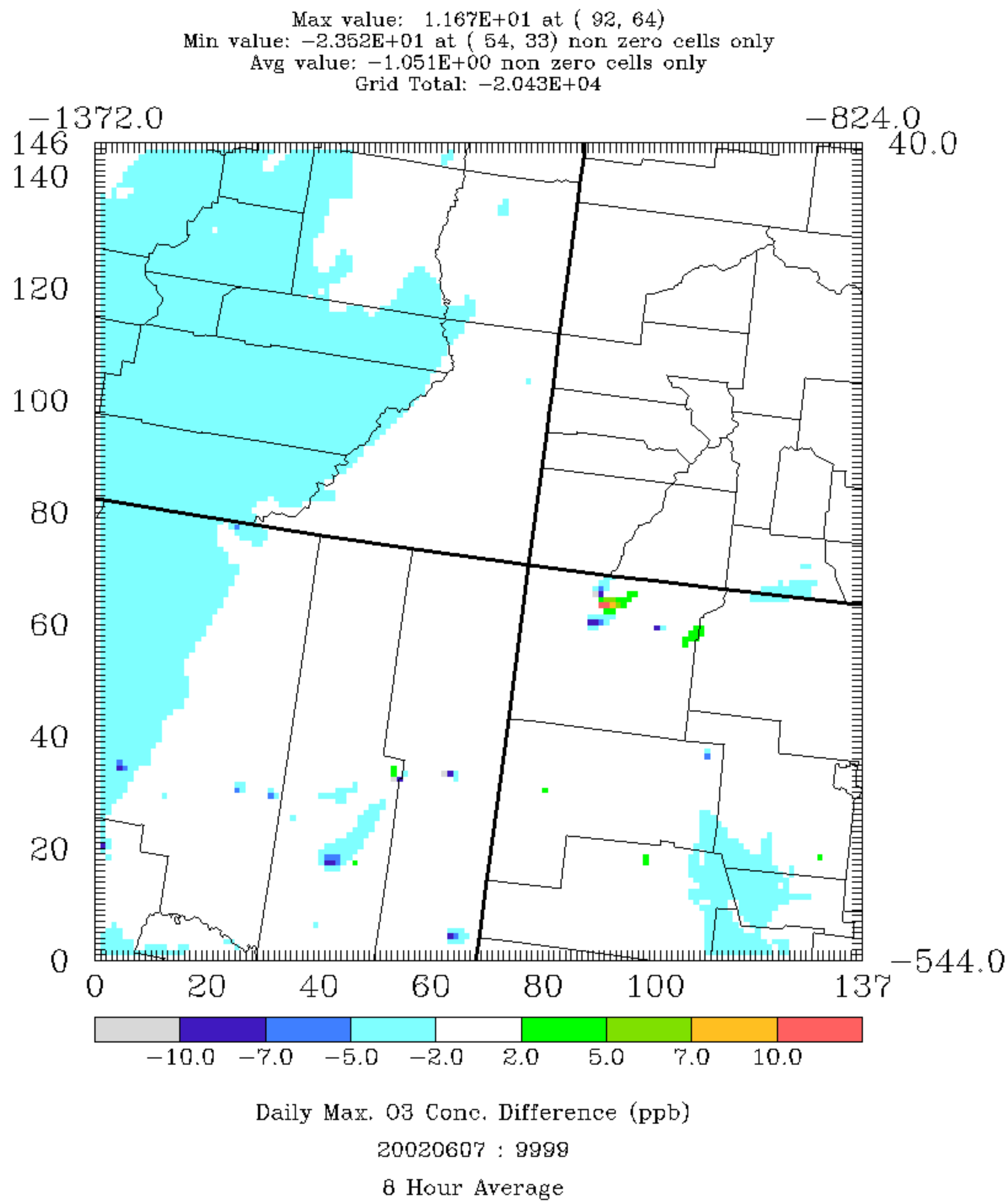

Figure B-4. Daily Maximum 8-hr Ozone Residuals (2007 minus 2002) on 7 June 2007.

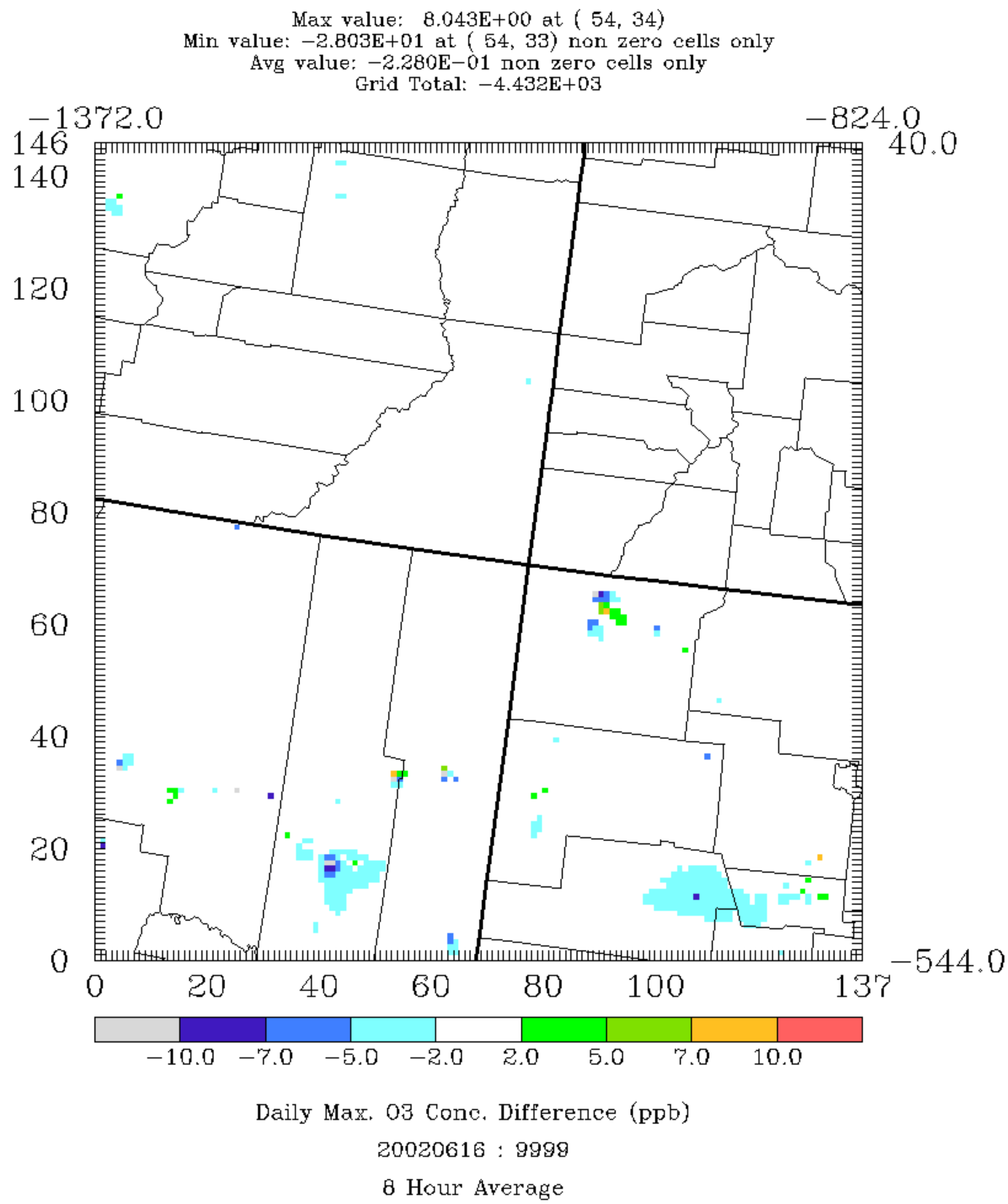

Figure B-5. Daily Maximum 8-hr Ozone Residuals (2007 minus 2002) on 16 June 2007.

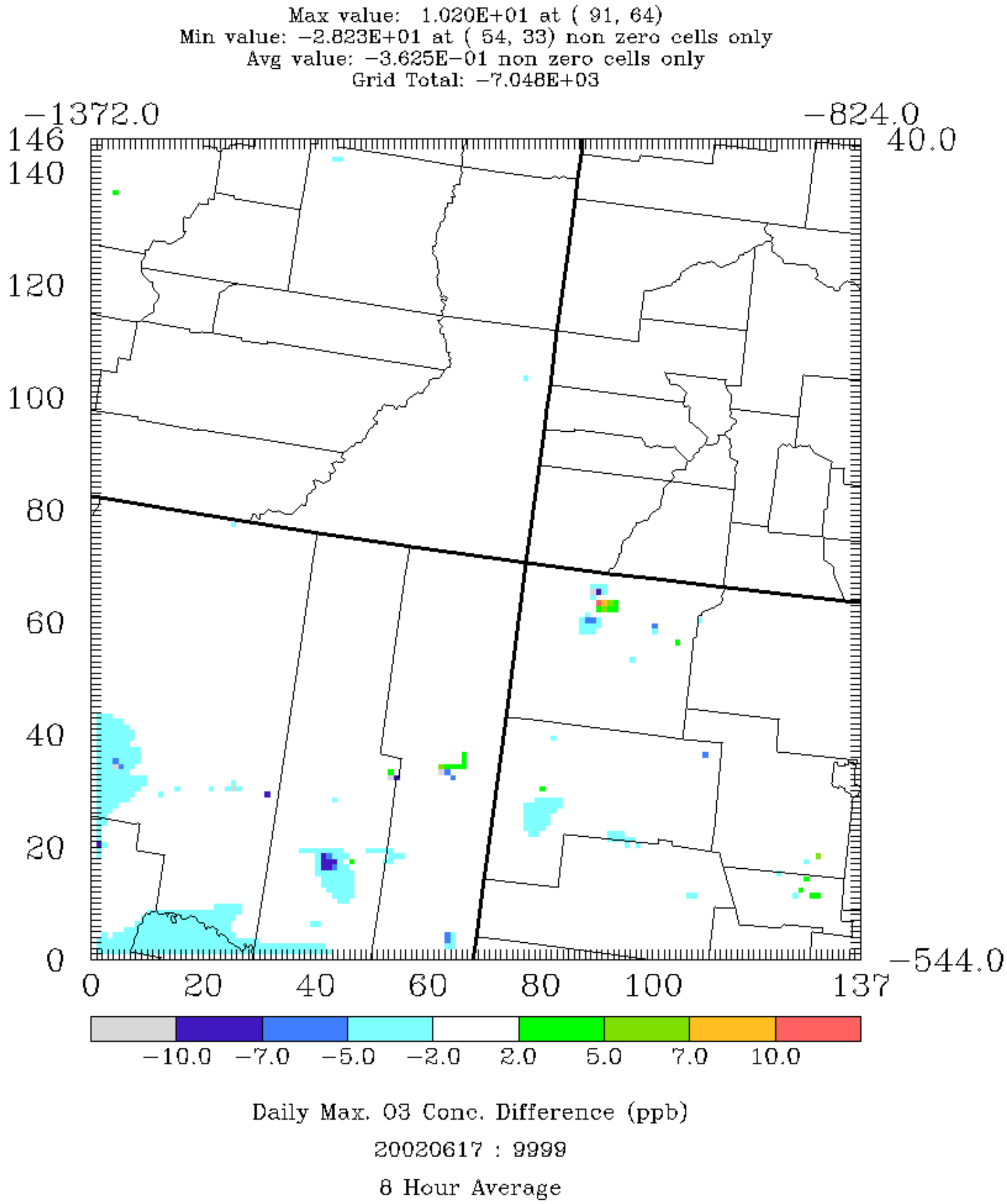

Figure B-6. Daily Maximum 8-hr Ozone Residuals (2007 minus 2002) on 17 June 2007.

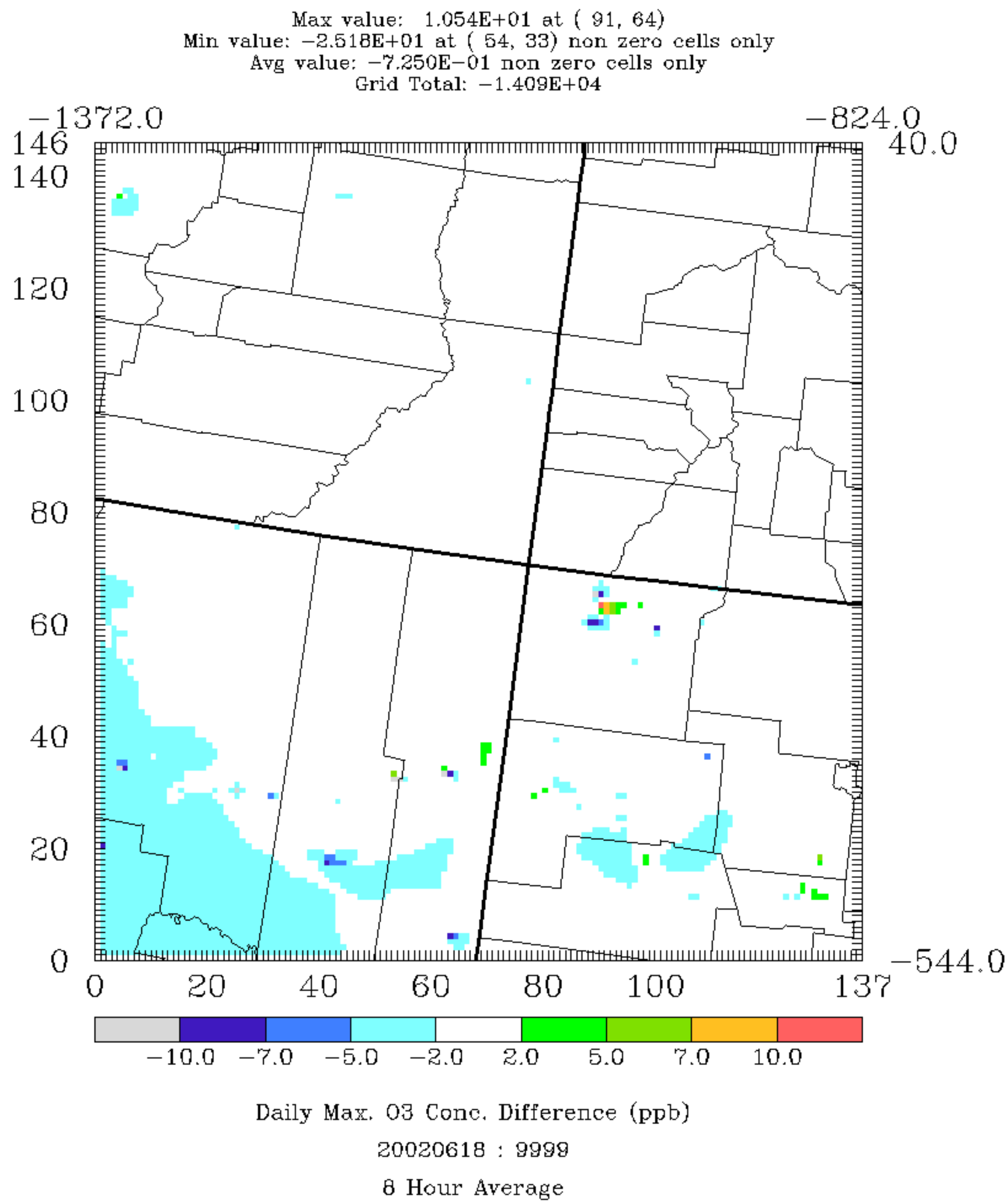

Figure B-7. Daily Maximum 8-hr Ozone Residuals (2007 minus 2002) on 18 June 2007.

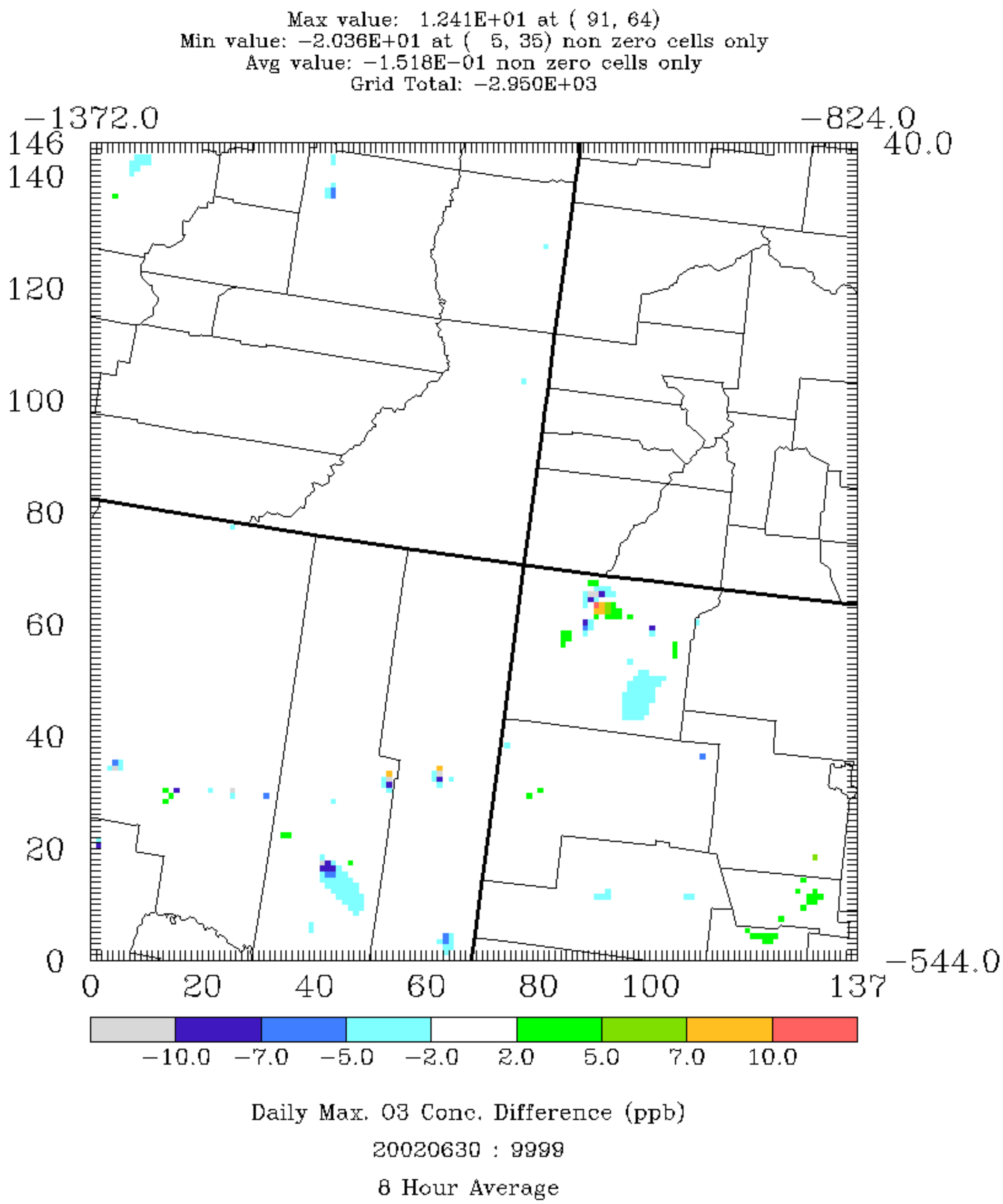

Figure B-8. Daily Maximum 8-hr Ozone Residuals (2007 minus 2002) on 30 June 2007.

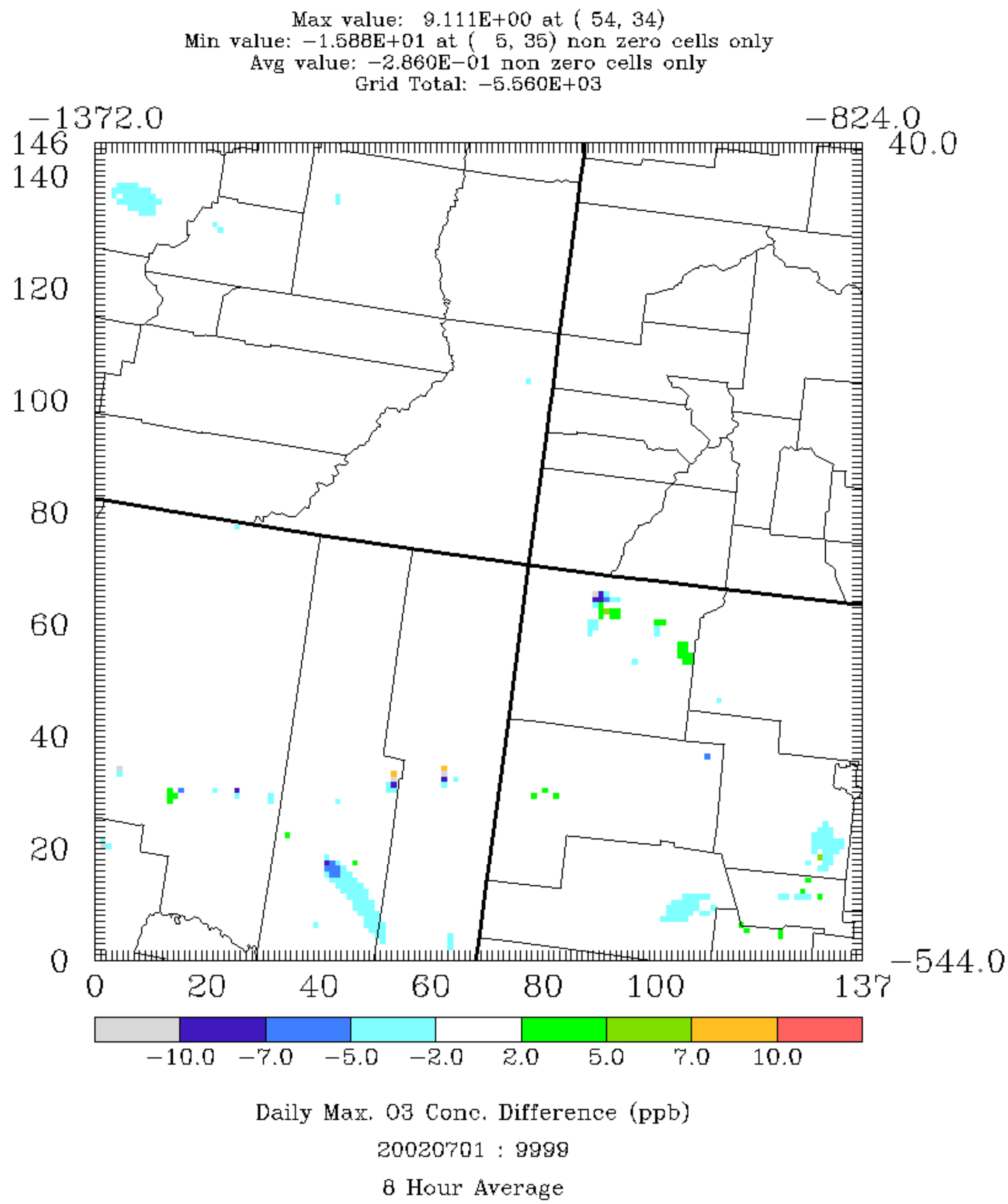

Figure B-9. Daily Maximum 8-hr Ozone Residuals (2007 minus 2002) on 1 July 2007.

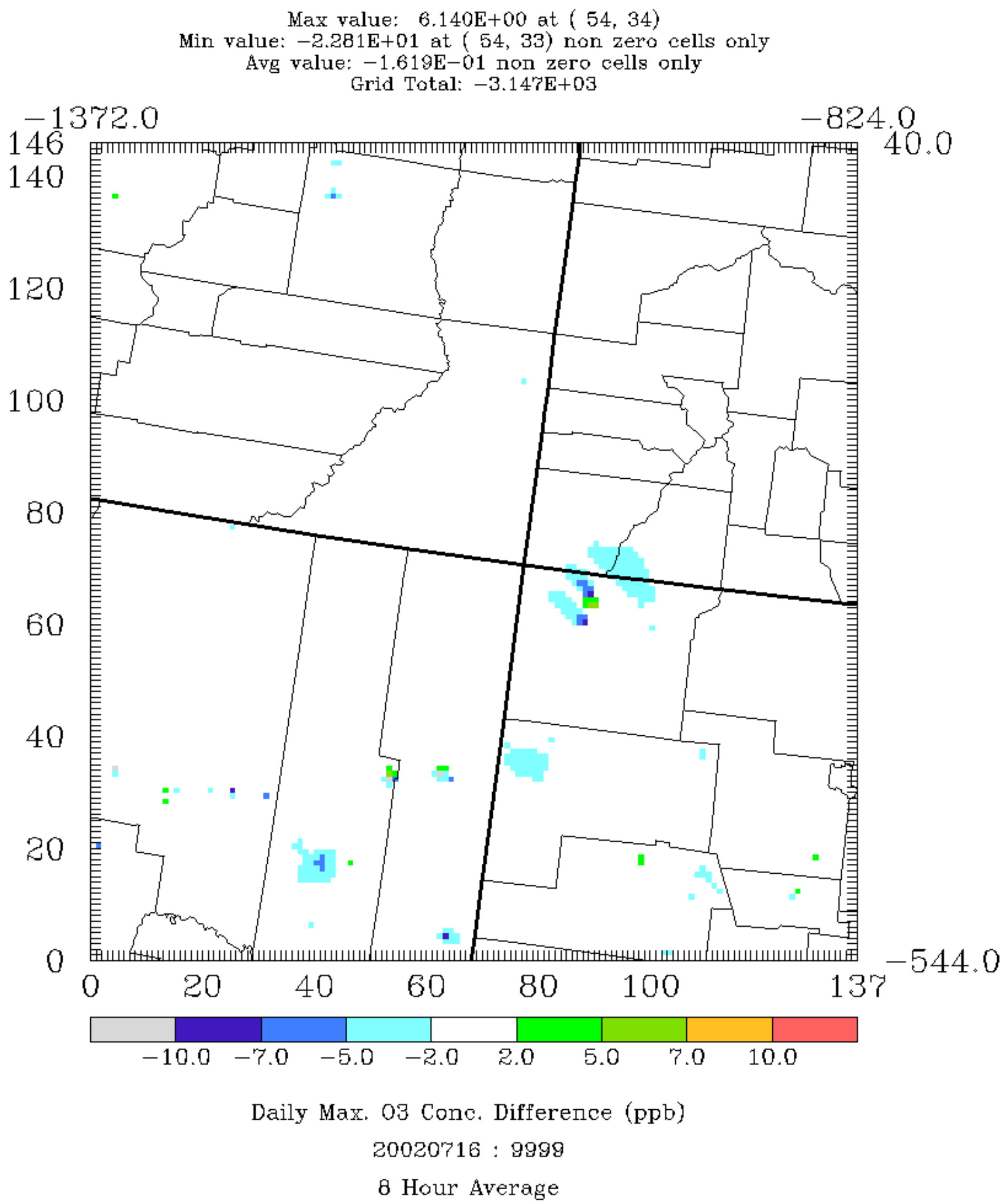

Figure B-10. Daily Maximum 8-hr Ozone Residuals (2007 minus 2002) on 16 July 2007.

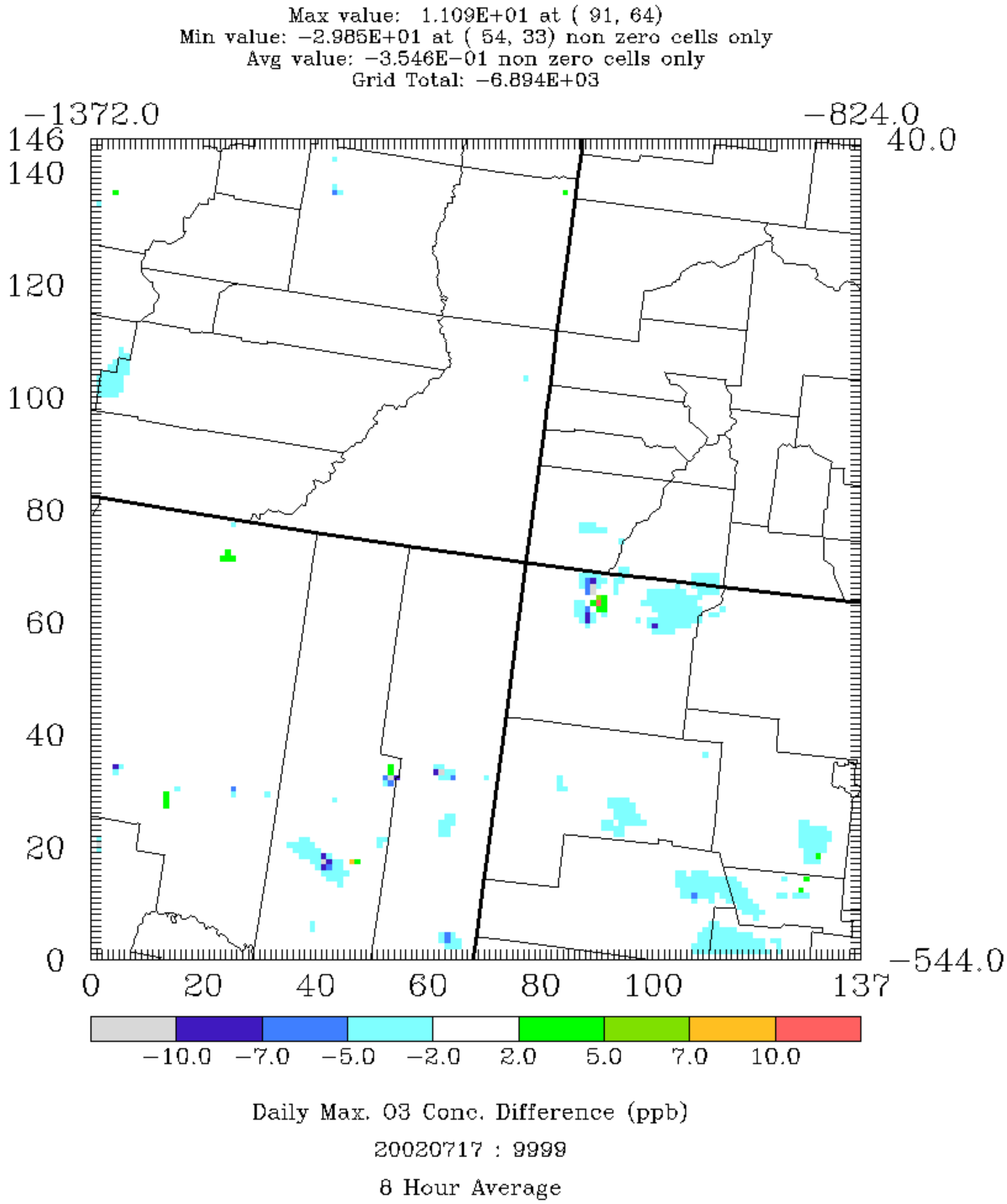

Figure B-11. Daily Maximum 8-hr Ozone Residuals (2007 minus 2002) on 17 July 2007.